Vol. VII. AUGUST, 1890. No. 4.

American Meteorological Journal.

A Monthly Review of Meteorology and Medical Climatology.

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ANN ARBOR, MICH., U. S. A.:
METEOROLOGICAL JOURNAL COMPANY.
19, 21 and 23 Huron Street.

AGENTS: B. Westermann & Co., New York; 2 Thalstrasse, Leipzig; and 189 Boulevard St. Germain, Paris.

Single Copies, 30 cents. Per Annum, $3.00. In European Countries, $3.25.

Entered at the Ann Arbor Postoffice as Second Class Matter.

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THE AMERICAN

METEOROLOGICAL JOURNAL.

[DOUBLE NUMBER.]

VOL. VII. ANN ARBOR, AUGUST, 1890. No. 4.

ORIGINAL ARTICLES.

THE TEMPERATURE AT ST. PETERSBURG, OCTOBER, 1889, TO APRIL, 1890.

By Dr. A. Woeikof.

The last seven or even eight months have been *exceedingly warm* in the north of Russia, in St. Petersburg, no month from October, 1889, to April, 1890, having a departure from the mean less than + 2.7° C. (4.7° F.) and March being even 5.0° C. (9.0° F.) warmer than the mean of 128 years. In that whole period March was only twice—in 1822 and 1836—warmer than in 1890. The seven months, October to April, were warmer than the mean in 1821-22, by 4.2° C.; 1889-90, 3.6°; 1826-27, 3.3°; and between 2° and 3° in 1755-56, 1768-69, 1790-91, 1881-82 and 1886-87. It is to be noticed that such a high temperature of the colder months was *experienced thrice in the last nine years*, while in the fifty-three years before there was no such warm year.

As the weather is very warm also in May (to the 22nd when I write) it is likely that the eight months, October to May, will be as warm, or perhaps warmer in this year than in 1821-22, when May was but a fraction of a degree warmer than the mean.

The seven months past were not only warm, but there was not the interversion of the order of the months so often experienced

in warm winters, as in 1863, 1866, 1882, when January was much warmer than December and February, but it was as if St. Petersburg was transported to a much warmer, and rather more continental climate. The mean temperature of the past seven months was very much like the mean of Kiev, which is situated on the same meridian, but 9° to the south of St. Petersburg. The greatest difference was in March, which was by 1° warmer in St. Petersburg than it generally is in Kiev.

The mean temperature of the summer at St. Petersburg is 16.2°. Thus a day with a temperature of 16° or above can be called a summer day for this climate. The period elapsed between the last summer day of 1889, (October 2), and the first summer day in 1890, (April 27), is but two hundred and seven days, while the mean period is two hundred and sixty-eight days, and the shortest till now were in 1881–82, 231; 1838–39, 240; 1774–75, 241; and the largest in 1821–22, 319; 1864–65, 314; 1884–85, 313.

Only once, in 1874, the last summer day was later than in 1889, it was October 3rd. As to the first, it was never yet observed so early, the earliest till now were April 30, 1882, and May 1, 1836.

The last summer day was August 11, in 1791 and 1884, and August 12, in 1821; the first, June 27, in 1822 and 1865, and June 26, in 1810. Thus there may be a lapse of ten and a half months between the last and the first summer day, and this year it was reduced to less than seven months.

The seven months just elapsed were also noticeable for the great number of days which were warmer than in any other of the one hundred and twenty-eight years. There were fifteen of these days, six in October, three in March and six in April. The greatest number of warmest and coldest days in the months October to April was:

	Warmest.	Coldest.
1770–71	13	3
1772–73	9	0
1781–82	0	6
1808– 9	0	10
1821–22	9	0
1852–53	1	7
1881–82	10	0
1889–90	15	0

The year from May, 1889, to April, 1890, was also foremost in this respect as seen below.

Greatest number of warmest and coldest days in a whole year:

	Warmest.	Coldest.
1757	16	3
November, 1759, October, 1760	0	12
April, 1770, March, 1771	15	2
1774	15	6
September, 1809, August, 1810	0	16
May, 1889, April, 1890	18	4

The coldest days in 1889 were in July, August and September. In the whole eight months elapsed, the end of October and beginning of December alone had days 8° or more below the mean, in the other months no day was even 5° below, while in November, from December 11 to January 17, and from February 27 to May 8, 1890, no day was even 3° below the mean.

TROMBES AND TORNADOES.

By H. Faye,
Membre de l'Institut, Président du Bureau des Longitudes, etc.

(CONTINUED FROM JULY NUMBER.)

The most characteristic trait of *trombes* and tornadoes is their form. It is remarkable that a meteorological phenomenon so complicated in appearance should affect a form susceptible of a geometric definition, that of a cylindro-conic surface of revolution with a vertical axis having the apex below. The same definition applies to storms or cyclones; a cyclone is nothing but an immense *trombe* reduced to its upper part, in form a frustrum of a cone.

These essentially mechanical phenomena should be the same everywhere. The differences are really of a physical nature purely; they depend upon the abundance or rarity of the upper cirrus, on the dryness or humidity of the lower strata, on the condition of the soil, dry and friable, or soaked with rain or hardened with ice. The only difference between Europe and the United States, is that in Europe they are rare and that in the interval of two catastrophes, the first has been forgotten. From the nature of this figure of revolution, entirely geometrical from above downwards, but somewhat altered by contact with the soil, it follows that all this mechanical edifice is comprised within the surface and admits no centripetal afflux from outside.

In the preceding article it has been seen, that there are three essential circles to be considered in a cyclone: 1st, the circle which limits the interior calm; 2d, the circle which limits the cyclone, properly speaking, on the surface; 3d, the projection on the ground of the circle which limits the mouth of the

cyclone above. It is between the two last that *trombes* and tornadoes appear, not upon its entire circumference, but on the dangerous side. In these regions are seen the signs which announce the proximity of a storm, that is, a calm scarcely interrupted by irregular puffs of air, a moist and oppressive heat, finally the appearance of thick clouds animated by irregular movements. At the base of one of these clouds appears one or more conical protuberances, which lengthen little by little and descend vertically. These are the gyrations which form in an upper current, concealed by the clouds, of which they invariably follow the movement of translation. It often happens that, by a mechanical property of gyrations, these neighboring whirls combine into one. This one then enlarges and descends faster, while progressing upon the same trajectory. The tornado terminates below in an obtuse point, like a sack elongated by placing a stone in it.

"While the tornado-cloud," says Mr. Finley, page 39 of his book "Tornadoes," "is traversing the atmosphere at some considerable distance above the earth, it may reach down so low as to just skim over the tops of the highest trees; descend to a level with the roofs of buildings, simply scaling off the shingles in spots or entirely on one side, leaving the roof-boards and rafters unmoved; removing the tops of chimneys; taking out all the fans in the wheel of a wind-mill and leaving every portion (even the tail) unharmed; take off the cornice without disturbing the remainder of the roof; removing simply the top board of a five-board fence, or one or two of the top rails of an ordinary rail fence. The tornado-cloud may, however, remain at a perfectly safe distance throughout its aerial course, and it then may be seen at a great height, moving solitary and alone like a huge balloon. While in this condition, it has not a few times been unwittingly taken for the latter object, but the mystery and sensation were entirely dispelled when the news came in from the surrounding country of the frightful power of this now silent monster."

Thus even where the tornado has not yet touched the earth, when its lower extremity is still closed, before any communication with the exterior air, it possesses already in itself a destructive energy. But see it, as it touches the earth! By this contact the whirling spirals are destroyed; the air brought from above escapes below around its foot with an inconceivable violence. Its formidable rumbling is heard at a distance. There

has now formed about the foot a cloud of dust, of debris, and of condensed vapor of water. The tornado then appears to have two heads, one in the clouds the other on the ground. Some persons, to give an idea of what they have seen, compare it to an hour-glass formed of two cones, opposite and one above the other. But it is enough to cast a glance at the picture of the tornado of Ercildoun, or of the photograph of that of Howard (August 28, 1884), reported by Mr. Finley in the work already named, to be assured that the lower part is only the *buisson* which has already been mentioned several times.

The body of the *trombe* is of an entirely different nature. It may be said to be enveloped in a sheath of mist, identical with the material of the cloud from which is formed this prolongation. It is for this reason that Buffon thought this matter must be viscous, so as to elongate indefinitely to furnish this envelope. The facts are more simple: the air which descends in the *trombe* while whirling is much colder than the surrounding warm and humid air which it would traverse in descending. A condensation of vapor is produced all around it and thus forms a misty sheath—quite similar to the upper cloud.

Here I naturally place the explanation of a point which might embarrass the reader. Among the 549 tornadoes (catalogued by Mr. Finley) of which the play of gyration has been indicated by observers, 528 turn from right to left (direct rotation) and only twenty-one turn from left to right (retrograde rotation). It is asked how these chance observers have been able to recognize, without being deceived the direction of the rapid gyration in which the cloud sheath does not sensibly participate. The observers judge by the movements of projection of the light objects composing the *buisson.* The air which escapes from the foot of the tornado, tangentially to its circumference, strikes the ground with the obliquity of the spirals themselves and reflects from the ground with the opposite obliquity, that is, in rising to a certain height. The same objects carried by the air around the tornado in planes which are tangent to this cylinder, and in the same direction as the rotation, will appear to turn around the *trombe,* and it is this false gyration, which is attributed by spectators to the tornado. Happily the appearance is here conformed to the reality, save in the point that the same objects appear to turn like a *trombe,* but ascending.

There is another remark which is no less worthy to be made. It is about the blackish mud with which the bodies of the vic-

tims of the tornado at Delphos, Mr. Krone's house, were plastered so singularly. This mud also covered the trunks of trees, the fences and the side of the walls still left standing. It was so incrusted on these objects, that when the attempt was made to remove it a few days afterward, it was necessary to use the hammer and chisel. This blackish mud is also found in European tornadoes. The workmen in the manufactory, destroyed August 19, 1845, in the environs of Rouen were found covered with this mud. It was precisely the same in the *trombe* of Moncetz which occurred October 19, 1874, on the left bank of the Marne. The earth was then soaked with previous rains; worked up by the whirling spirals of the *trombe*, it was thrown in the form of mud, obliquely to the horizon; it formed part of the *buisson* of debris, and was plastered upon neighboring objects.

The study of the vaporous sheath of the tornado has a real importance. In certain *trombes* observed at sea, it is interrupted sometimes throughout a considerable portion of its length, especially at first. It was for this reason that the *trombes* described by Dampier were at first but little visible below the cloud from which they proceeded, even though they descended in reality to the waves upon which their action was already visible. Some physicists like M. Peltier, concluded from it that the cloud strongly electrified, attracted the water of the sea below it, and that under this influence the cloud finally sent out a misty prolongation to the water, in such a way as to make a conductor, to operate a silent discharge of the electricity.* But it is evident that this temporary interruption of the cloud sheath depends upon the fact that the air coming from above is not at first cold enough to provoke the condensation of the humidity of the surrounding air. In these interruptions, the tube of the *trombe* is hollowed throughout its entire circumference; it is a cylinder broken and not closed at the point, as is the lower extremity of the *trombe* when it is seen to descend entire.

Movement of Translation.—This is an important phenomenon. There are neither cyclones, *trombes* or tornadoes, which are motionless. If, by chance, it has been thought motionless, it is because the spectator was at a distance upon the trajectory. The velocity varies much in different *trombes*; the mean is 20 meters per second. This is 72 kilometers per hour, the velocity of a lightning express train.

* The pretended fact is often cited in support of this assertion, that thunder ceases to roll from the time the *trombe* reaches the surface of the water.

This explains the astonishing rapidity with which a tornado destroys a house situated in its path. If its diameter is 200 meters, it crosses this diameter in 10 seconds. In less than 10 seconds the *trombe* has passed, leaving only ruins behind it. This would be incomprehensible if it were not a question of whirls analogous to cyclones, but these gyrations are much more rapid, and their linear velocity attains, and perhaps exceeds, the half of that of a musket ball.

The great difference between cyclones and tornadoes is the slight extent of trajectory of the latter. It varies from 300 yards to 300 miles. That which is most striking in this is the direction. The tornado is not running with the speed of a galoping horse or a lightning express train, at hazard. Invariably in all latitudes, at least from the 30th degree, it progresses from a point between the west and the south of the horizon toward the opposite point between the north and east. In France, the double tornado of 1788 went to the NNE; the tornado of that year, which cut a vast path in the forests of the department of Doubs, progressed to the ENE. In the U. S. their most ordinary direction is to the northeast. We have seen above that it is, so to speak, under the wing of the cyclone that tornadoes are produced; we see that in reality they follow almost exactly the same route as cyclones. But this great question will be reserved for the succeeding part of this work. What may be said at present is, that the progress of the tornadoes has nothing to do with accidents of surface. "The tornado-cloud" says Mr. Finley, page 42, in his book on tornadoes, "pursues a general course to the northeast without regard to the character of the earth surface, and if your buildings are in line of its destructive path, whether upon a hill, in a valley or within a ravine, they are subject to its violence. . . . Repeated investigations have shown that buildings were destroyed with as great violence and completeness upon high lands as in valleys. . . . In many instances the funnel cloud has passed from one ridge to another, doing damage on both, but skipping the intervening depression. Again it has followed high divides for several miles when they coincided with the general course of movement. Ridges and valleys are almost invariably crossed at right angles when their courses are from northwest to southeast."

It is also a property of cyclones to pass above oceans and continents without modifying their trajectory. Tornadoes which

have their origin at a low level may be on the contrary arrested or intercepted by chains of mountains.

Let us repeat that this movement is the touchstone of theories. It is that which has decided the real masters of the science to place the origin of tornadoes in the region of clouds, there where may be encountered rapid currents to transport to a distance masses of air so that an initial gyration may be produced. The only difficulty is, that they wish to feed and animate this gyration by an ascending current of air, and that they persist in making it descend to the ground without bringing down a single molecule of air.

Inclination of Tornadoes.—This inclination has been mentioned already by Dampier. It is produced in the same direction as the progression, which must embarrass the old meteorologists habituated to placing the origin below. It is a phenomenon analogous to that which we have already analyzed in cyclones; but, while these present only traces, in the elongated form of the isobars of which the centers are distributed longitudinally over a small portion of the trajectory, it is more striking for tornadoes of great velocity. If Mr. Finley does not speak of it in the great report which serves us for a basis, it is because the persons consulted were almost upon the trajectory of the tornadoes. They have not distinguished the inclination of the tornadoes in seeing them come from afar. At the moment of being menaced their minds were not in condition to observe such details. The instructions of the Signal Office are very explicit however, in this particular: "Did the tornado-cloud remain in a vertical position as it traveled forward, or was the tail of it inclined; in what direction and how many degrees from the perpendicular?" The *trombe* of Lake Geneva, of which I have spoken, (August 19, 1887), presented an inclination which was very appreciable. M. Testuz who observed it, says:* "The column was somewhat inclined, and when the foot was before Treytorren, the summit seemed to have arrived over the village of Chexbres." The inclination was in the direction of the progression, for the *trombe* passed to the NE, and Chexbres was also NE of Treytorren. If it were possible to reunite on this point the necessary indications, one would be in position to deduce therefrom the mean velocity of the descent of the spirals of the whirl.

Let us repeat here what has been said of cyclones: it is not

**Comptes Rendus*, 1889, Vol. 105, p. 415.

the axis of gyration which is inclined, but the axis of the figure, or rather the line of the centers of the successive spirals. The axes of gyration of the spirals remain appreciably vertical, so that the work of the spirals which reach the ground is the same as if the tornado was vertical. A great inclination would scarcely alter the appearance of the *buisson* of the *trombes* at sea, such as those of which Admiral Mouchez has published drawings.

This oblique dissemination of the gyrations of a tornado is explained in my theory. These gyrations are connected with each other, like the spirals of a helix. A very rapid movement of gyration and of descent the length of a helicoidal nappe confers a sort of rigidity or rather of elasticity to the whole, which allows the spirals to be displaced a little horizontally without separating. It would be no longer the same circular gyration, simply superimposed. We have in this case seen the *trombe* enlarge considerably in the direction of the translation instead of inclining without change of form.

Swaying of Tornadoes.—When a report is made upon a topographical chart of the successive positions of the phenomenon, for the purpose of tracing the trajectory, a zig-zag of small extent is often noticed, which does not appreciably alter the general direction of the progression. This may be compared to a simple straight line throughout its length, and the exceptions do not exceed, in relation to this line, more than two or three hundred meters. This suffices to cause the trajectory to pass from the south to the north of a house, or inversely, as seems to have been the case with Mr. Krone's (Delphos tornado), previously cited. It is a phenomenon analagous to the inflections often presented by *trombes* at sea which are more slender and more flexible. It is evidently due to the action of slight winds which blow fitfully at different heights, precisely at the time when tornadoes and *trombes* appear. This action will be understood if it is remembered that the descending spirals of a tornado are exclusively formed of air of which the density is a little less than that of the surrounding air, and that they are, nevertheless, firmly united with each other, in some sort, by the rapidity and nature of the movement which constitutes them.

Vertical Movement of Tornadoes.—When a tornado descends from the clouds under the form of a long conical pocket closed below, we have seen that it can progress for some time without touching the ground. It executes then no work below it. If it reaches the ground the interior gyrations then encounter ob-

stacles and their work of destruction at once begins. But it often happens that the tornado rises for some time before having finished its entire course; the diameter of the horizontal section, which the surface of the ground produces in this inverted cone, diminishes, and soon the tornado is entirely disengaged, assumes its form of a cone closed at the summit and travels thus apex downward without touching the earth, to redescend a little farther on and to recommence its ravages. "Sometimes," says Mr. Finley, "upon the lifting of the tornado-cloud from the earth, it does not again descend for a distance of several miles, at times making the return movement twenty or thirty miles distant, the intervening space proving a complete blank in its track. More frequently, however, these gaps are from one to five miles in length."

When it travels thus, the apex in the air, a little above the ground, the air does not issue from the point, otherwise it would be surrounded by a visible mist which has never been observed. The terrible rumbling of the tornado suddenly ceases; the monster, as Mr. Finley says, continues its route silently. It has often been taken for a balloon.

These phenomena are not peculiar to the tornadoes of the United States. They have been noted in France in the tornadoes of Assonval (1822), of Monville Malauney (1845), of Vendôme (1871), of Moncetz (1874), etc.

The meteorologists who hold in favor of ascending *trombes* think that those which seem not to touch the earth ought no less to exercise some action on the ground below. Mr. Finley, while examining step by step the trajectory of one of these tornadoes, has stated that all trace of destructive energy disappears when it leaves the ground.

The explanation of these singular phenomena is quite simple. The tornadoes originate in a current at the expense of the inequalities of velocity of this current; it is from it that the tornado draws the energy of its gyration; it is there that it draws the force necessary to cause the whirling masses of air to descend into strata more and more dense. If this energy becomes enfeebled, the atmospheric pressure, vanquished up to this time, takes the upper hand and forces the spirals to ascend more or less; if it is too much diminished the tornado rises to its origin, as some rivers do, but more slowly than it descended, and disappears. We will return to this point in another article.

There remains to be done here, what has already been done

for cyclones. After having established that cyclones originate in the upper currents, at a great altitude, we have tried to show, by the examination of the great movements of the atmosphere, 1st, that such currents really exist; 2nd, that the whirls which form there have the proper direction of gyration. We must then search in much less elevated regions for the accidental currents, of slight duration, where tornadoes originate, and show the direction of their gyration. This question is reserved for succeeding articles, as are also the electrical phenomena which are developed so generally on the flanks of cyclones and sometimes in the *trombes* themselves.

Conclusion.—Here are a large number of facts, sufficiently observed by competent persons. Any one may see how far my theory is justified by these facts. It seems to me that a comparison would plainly show:

1st. That there are no centripetal movements, neither at the foot of *trombes* or tornadoes nor toward the base of cyclones.

2nd. That *trombes*, tornadoes, typhoons and cyclones are varieties of the same mechanical type of which the analogy may be found in water courses. They are descending whirls with vertical axes, originated in the upper currents of the atmosphere, and follow the direction of these currents.

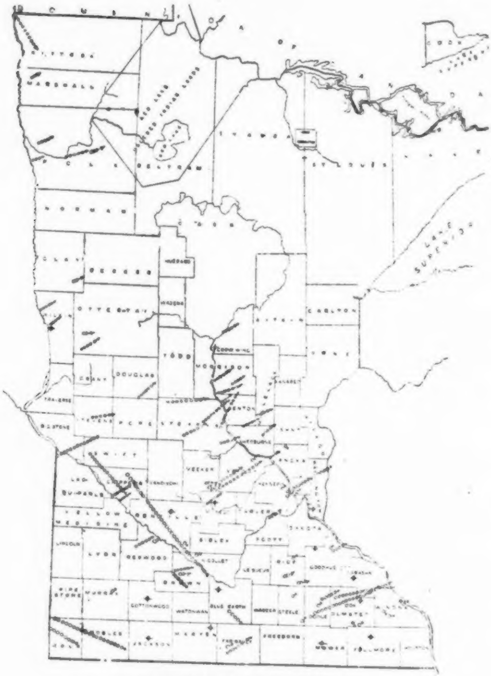
The idea that *trombes* pump up to the clouds the water of the ocean is then an illusion.

The inconvenience of this prejudice in the minds of the sailors is that it refers to matters connected with navigation. Unfortunately the word *waterspout* tends to legitimatize and propagate this opinion. Perhaps it would be well to replace it by that of *airspout.*

This proposition is not mine. It was made nearly a century ago, by a celebrated citizen of Boston, Dr. Perkins, in a letter to Benjamin Franklin, dated October 23, 1792 (Franklin's Works, Vol. II, page 18). Here are his words:

"*Query:* Whether there be any credible account of a whirlwind's carrying up all the water in a pool or small pond; as when shoal and the banks low, a strong gust might be supposed to blow it all out?"

"Whether a violent tornado of small extent, and other sudden and strong gusts, be not winds from above, descending nearly perpendicular; and whether many that are called whirlwinds at sea are any other than these; and so might be called *airspouts*, if they were objects of sight?"



TORNADOES IN MINNESOTA.

STATE TORNADO CHARTS.—MINNESOTA.

By Lieut. Jno. P. Finley, Signal Service, U. S. A.

Table I.—*Tornadoes in Minnesota.*

Period of observation, 34 years, 1855-1888.
Total number of storms,—89.
Year of greatest frequency, 1886,—28.
Average yearly frequency,—5.2 storms.
Year in past ten (10) years, no report of storms,—none.
Month of greatest frequency, July,—24 storms.
Day of greatest frequency, April 14th,—13 storms.
Hour of greatest frequency, 3 to 4 p. m.
Months without storms, January, February, March and December.
Prevailing direction of storm movement, NE.
Region of maximum storm frequency, central and southern portions.

TABLE 11.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of Minnesota for a period of 34 years, from 1855 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Goodhue	June —.	1855				
Sherburne.	August 8.	1859	10 a. m.	NE.	Funnel.	
Goodhue	June 16.	1865		NE.	"	
Stearns		1870	4 p. m.	NE.		5,280.
McLeod	August 25.	1875			Funnel.	
Fillmore.	April 13	1876			Waterspout.	
Crow Wing	May 20.	1876				
Ramsey	May 30.	1877	Afternoon.	NE.		
Washington	June 14.	1877	"	NE.		
Hennepin	June 29.	1877		NE.	Funnel.	
Martin	July 1.	1877				
Wilkin	July 7.	1877	Afternoon.			
Goodhue	July 3.	1879	11:30 p. m.	E 20° N.	Funnel.	150.
Murray	June —.	1880		NE	"	
Blue Earth	June 5.	1880		NE.	"	
Mower.	June 11.	1880	Afternoon.	NE.	"	
Olmstead.	August 26.	1880		NE.	"	
Dodge	September —	1880		ENE.	"	
Faribault.	June 12.	1881	4 p. m.	NE.	"	
Rice	"	1881	5 p. m.	NE.	"	
Winona	July 11.	1881	"	NE.	"	
Lac-qui-parle, Big Stone and Swift	"	1881	5:50 p. m.	NE.	"	20 to 100.
Nicollet and Brown	July 15.	1881	3:15 p. m.	SE.	"	30 to 1,574.
Brown	"	1881	5 p. m.	SE.	"	2,640.
Blue Earth	"	1881	6 p. m.	SE.	"	1,320 to 2,640.
Olmstead	"	1881	Afternoon.	E.	"	
Renville	"	1881	2 p. m.	E. 50° S.	"	1,320 to 10.560.
Swift	"	1881	Afternoon.	SE.	"	5,280 to 10.560.
Cottonwood	July 16.	1881	"	E.	"	
Redwood	"	1881	"	NE.	"	
Steele	September 29.	1881	"	NE.	"	
Nicollet	November 25.	1881		NE.	"	
Jackson	May 8.	1882		NE.	"	
Steele	April —.	1883		NE.	"	
Wabasha	April 13.	1883	Night.	NE.	"	
Anoka	May 2.	1883	11:20 p. m.	SE.	"	2,640.
Wabasha and Olmstead	July 21.	1883	11:45 a. m.	E 20° N.	"	2,640.

TABLE II.—*Continued.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Olmstead	August 19.	1883	Afternoon.	NE.	....	....
Dodge and Olmstead	August 21.	1883	6:36 p. m.	E 30° N.	Funnel.	1,320 to 3,960.
Winona	"	1883	7:30 p. m.	E.	"	660 to 1,320.
Winona	"	1883	8 p. m.	SE.	Balloon.	660 to 1,320.
Olmstead	October 9.	1883	12 m.	E 40° N.	Funnel.	1,320 to 2,640.
Olmstead	June 30.	1884	8 p. m.	SE.	"	....
Rock and Nobles	July 21.	1884	1:30 p. m.	E 30° S.	"	....
Rock	July 28.	1884	3 p. m.	SE.	"	....
Hennepin, Ramsey and Washington	September 9.	1884	5 p. m.	E 30° N.	"	2,640.
Kittson	June —.	1885	Afternoon.	SE.	"	1,320 to 2,640.
Wright	July 8.	1885	3:25 p. m.	E 20° N.	"	150.
Winona	"	1885	5 p. m.	NE.	"	....
Olmstead	"	1885	6:30 p. m.	E.	"	....
Douglas	April 14.	1886	Afternoon.	NE.	....	....
Benton and Stearns	"	1886	4 to 4:30 p. m.	E of N.	Funnel.	300 to 1,800.
Stearns	"	1886	4 p. m.	NE.	"	....
Crow Wing	"	1886	6:10 p. m.	NE.	"	....
Sherburne and Stearns	"	1886	3:30 p. m.	NE.	"	5,280 to 8,150.
Morrison	"	1886	4 p. m.	NE.	"	2,640.
Benton	"	1886	5 p. m.	N 30° E.	"	475.
Benton	"	1886	4 p. m.	NE.	Cylindrical.	1,320.
Morrison	"	1886	"	N 15° E.	Funnel.	660.
Stearns	"	1886	"	NE.	"	350.
Mille Lacs	"	1886	"	NE.	"	....
Morrison	"	1886	3 p. m.	NE.	"	....
Polk	"	1886	4 p. m.	NE.	"	....
Polk	June 11.	1886	8:30 p. m.	ENE.	"	....
Chippewa	June 14.	1886	2 p. m.	NE.	Elephant's trunk.	120.
Chippewa	"	1886	About 2 p. m.	NE.	Funnel.	....
McLeod	June 21.	1886	2:30 p. m.	NE.	"	100 to 350.
Brown	July 8.	1886	Midnight.	ENE.	....	....
Polk	August 9.	1886	2:45 p. m.	E.	....	1,320 to 2,640.
Freeborn	August 15.	1886	Afternoon.	Easterly.	Funnel.	....
Stevens	"	1886	"	"	"	1,320 to 2,640.
Wilkins	"	1886	"	"	....	....
Otter Tail	"	1886	About 8 p. m.	"	....	....
Wilkins	"	1886	Evening.	NE.	Funnel.	2,640 to 5,280.
Marshall	"	1886	5 p. m.	NE.	....	1,320.

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Wright	August 21.	1886	4:30 to 5 p. m.	NE.	Funnel.	1,320 to 2,640.
Wright	"	1886	5:30 p. m.	ESE.	"	1,320.
Redwood	"	1886	4:20 p. m.	NE.	"	2,640.
Polk	April 9.	1887	4 p. m.	NE.	Conc.	Narrow.
Otter Tail	May 1.	1887	4:30 p. m.	E.	Funnel.	1,320.
Clay	"	1887	Afternoon.	NE.	"	800 to 1,000.
Ramsey	"	1887	6 p. m.	NE.	"	1,320.
Wright	June 18.	1887	10 a. m.	E.	"	500 to 1,200.
Rice	July 25.	1887	11 p, m.	Easterly.	"	250 to 500.
Rice	April 4.	1888	Afternoon.	NE.	"	1,320.
Scott	July 6.	1888	3:45 a. m.	NE.	....	2,640.
Brown	"	1888	Afternoon.	Easterly.	Funnel.	800 to 1,200.
Wright	July 31.	1888	5 p. m.	NE.	"	1,320.
Wright	August 4.	1888	4:30 p. m.	NE.	"	2,640.

TABLE III.—*Relative frequency of Tornadoes by months and days, for Minnesota.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
April	4, 9, $(13)^2$, $(14)^{13}$ and (—)	5	18
May	$(1)^3$, 2, 8, 20 and 30	5	7
June	5, $(11)^2$, $(12)^2$, $(14)^3$, 16, 18, 21, 29, 30 and $(—)^3$	10	16
July	1, 3, $(6)^2$, 7, $(8)^4$, $(11)^2$, $(15)^6$, $(16)^2$, $(21)^2$, 25, 28 and 31	12	24
August	4, 8, 9, $(15)^6$, 19, $(21)^6$, 25 and 26	8	18
September	9, 29 and (—)	3	3
October	9	1	1
November	25	1	1
(—) Blank	(—)	1	1
Total		46	89

NOTE.—The blank (—) signifies date missing.

TORNADOES IN MISSISSIPPI.

STATE TORNADO CHARTS.—MISSISSIPPI.

BY LIEUT. JNO. P. FINLEY, SIGNAL SERVICE, U. S. A.

TABLE I.—*Tornadoes in Mississippi.*

Period of observation, 66 years, 1823-1888.
Total number of storms,—52.
Year of greatest frequency, 1884,—9 storms.
Average yearly frequency,—2.5 storms.
Year in past ten (10) years, no report of storms,—none.
Month of greatest frequency, April,—21 storms.
Day of greatest frequency, April 22nd,—10 storms.
Hour of greatest frequency, 2 to 3 P. M.
Months without storms, July, September, October and December.
Prevailing direction of storm movement, NE.
Region of maximum storm frequency, northeastern and southern portions.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of Mississippi for a period of 66 years, from 1823 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Adams	May —.	1823		E.		
Adams	"	1824				
Adams		1862 or '33				
Adams	May 7.	1832	Afternoon.			
Adams	"	1840	2 p m.	NE.	Large masses as if white spray fell to the earth	10,560.
Adams	June 16.	1842				
Grenada	May —.	1846				
Copiah and Claiborne	May 16.	1853		NE.		
Webster	April 30.	1866	Night.			600.
Lincoln	April 15	1874				
Pontotoc, Union, Tippah and Alcorn	March 10.	1875	9 p. m.	NE.		1,000.
Alcorn	March 16.	1875				
Itawamba	May 1.	1875				
Copiah	March 11.	1876	12:15 a. m.	NE.		
Issaquena	May 18.	1878	Afternoon.			
Webster	March 27.	1879	12 m.	NE.	Funnel	900.
Benton	April 14.	1879		E.	"	
Harrison	August 22.	1879	Afternoon.	NE.	"	100.
Adams	April 15.	1880	"	NE	"	
Issaquena	April 22.	1880	1:30 a. m.	NE.	"	
Noxubee	April 25.	1880	8:30 p. m	NE.	"	2,000 to 4,000.
Yazoo	April 29	1880	Afternoon.	NE.	"	500 to 800.
Jefferson	March 18.	1881	2:30 p. m.	NE	"	200 to 560.
Tunica and De Soto	April 12.	1881	2 p. m.	ENE.	"	300 to 1,000.
De Soto	April 27.	1881	4 p. m.	E.	"	660 to 1,320.
Jefferson	November 11.	1881		NE.	"	
Clay	March 27.	1882		NE.	"	660 to 1,320.
Clay	April 7.	1882		NE.	"	1,320 to 2,640.
Smith	April 22.	1882		NE.	"	
Copiah and Lawrence	"	1882	12:15 p. m.	E 10° N.	"	2,640.
Scott, Newton and Neshoba	"	1883	4:10 p. m.	NE.	"	
Jefferson	"	1883	10:45 a. m.	NE.	"	
Monroe and Clay	"	1883	12:30 p. m.	NE.	"	
Copiah, Simpson and Scott	"	1883	1:10 p. m.	NE.	"	1,320.

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Copiah, Newton, Smith, Simpson, Lauderdale and Kemper.	April 22.	1883	3 p. m.	NE.	Funnel.	1,320.
Choctaw, Oktibbeha and Clay	"	1883	1:30 p. m.	NE.	"	"
Winston	February 19.	1884	Afternoon.	ENE.	"	2,640.
Lowndes	"	1884	11:30 a. m.	NE.	"	900 to 1,200.
Oktibbeha	March 11.	1884	2 p. m.	NE.	"	....
Clay	"	1884	"	NE.	"	375.
Clay	"	1884	3:30 p. m.	NE.	"	1,320 to 2,640.
Lauderdale	"	1884	9 p. m.	NE.	"	300 to 420.
Newton	March 12.	1884	5:30 p. m.	NE.	"	....
Clay	March 17.	1884	1 p. m.	NE.	"	900.
Carroll and Clay	April 14.	1884	2:40 p. m.	NE.	"	1,320.
Clay	January 11.	1885	5 p. m.	NE.	Balloon.	....
Lowndes	March 12.	1885	6:30 p. m.	E.	Funnel.	1,000.
Lowndes	March 20.	1886	8 a. m.	NE.	....	....
Harrison	April 28.	1886	Afternoon.	....	....	2,640.
Bolivar	April 22.	1887	4 p. m.	NE.	Funnel.	Narrow.
Adams	April 23.	1887	"	NE.	"	750 to 1,000.
Marshall	May 27.	1888	Evening.	Easterly.	....	2,640.

TABLE III.—*Relative frequency of Tornadoes by months and days, for Mississippi.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January	11	1	1
February	$(19)^2$	1	2
March	10, $(11)^5$, $(12)^2$, 16, 17, 18, 20, $(27)^2$ and 28	9	15
April	7, 12, $(14)^2$, $(15)^2$, $(22)^{10}$, 23, 25, 27, 29 and 30	10	21
May	1, $(7)^2$, 16, 18, 27 and $(—)^3$	6	9
June	16	1	1
August	22	1	1
November	11	1	1
(—) Blank	(—)	1	1
Total		31	52

NOTE.—The blank (—) signifies date missing.

TORNADOES. FIRST PRIZE ESSAY.

BY LIEUT. JNO. P. FINLEY, U. S. A.

General Remarks.—Our earth floats, as it were, in a medium called the air, and considered as a whole, the atmosphere. We are living at the bottom of this atmospheric sea. This vast envelope does not rest upon a uniform surface, but on the contrary, one of great variety.

The heat of the sun falls upon the atmosphere, passes through it, and, upon the diversified surface of the earth, works a multitude of changes that modify the general motions which arise in this envelope, under the influence of the earth's rotation.

The sun's heat is the *primum mobile* which sets in motion the various disturbances of the atmospheric sea, and there is no rest from the incessant convulsions which as constantly form and disappear as one day succeeds another.

Some of these disturbances are extremely local in extent and others are enormously large. The former may have a radius of a few yards, while the latter reach several hundred miles.

There are other peculiar and important differences which will be considered in another portion of this paper.

The conditions are, then:

1. The earth with a vast surface of great diversity.
2. The revolution of this body upon its axis.
3. Surrounding the earth, a gaseous envelope of great elasticity.
4. Solar radiation.

The results are:

1. Destruction of atmospheric equilibrium.
2. Incessant motion of the atmosphere.
3. Systems of winds of great extent.
4. The formation of large disturbances having independent circulatory movements of air of considerable force.
5. The development of small disturbances with independent circulation of extreme force.

The last paragraph relates particularly to the subject of this paper. We have found that the atmosphere is constantly in motion and why. We have learned that such motion results in disturbances involving a limited portion of the medium, and that such portion varies greatly in superficial extent.

The large areas of disturbance we shall call "lows," cyclones

or general storms, and the small areas, tornadoes. The former will not be discussed independently, but only as related to the latter.

It may be stated generally that cyclones arise from abnormal irregularities in the distribution of temperature and moisture, whereby there is a greater specific gravity of the atmosphere in some places than in others. There also appear to be regions of permanent low pressure which act as a sort of breeding ground for storm areas.

Such local temperature disturbances give rise to interchanging motions between the central and exterior part of the storm area, and thus is formed an independent circulation or giant eddy which is propagated through the atmosphere until dissipated by various causes.

There is no actual whirl in the air because the radius of the area is too great; but only an incurving of the winds, which gradually brings the air from the circumference towards the centre of the disturbance.

Conditions of Tornado Development.—Tornadoes form in connection with cyclonic areas of low pressure, to which they bear certain relations that can be defined.

Not all low pressure areas develop the conditions necessary for tornado formation, which are: 1st, Unstable equilibrium. 2nd, A gyratory motion of the air relative to some centre of circulation. The second condition is always present, to a greater or less degree, in every cyclone, but the combination of the two, the *sine qua non* of tornadic development, fortunately, for some very good reasons, occurs with much less frequency.

There is good reason for the opinion that a certain form of the area of low pressure (trough-like, trending north and south or northeast and southwest) is more conducive to tornado conditions than any other. Such a form of depression brings in closer proximity the opposing conditions of heat and moisture of the northwest and southeast quadrants of the low, which state of things is especially favorable to the development of unstable equilibrium (the most important factor in tornado generation) in the southeast quadrant.

It is now no longer a mooted question that tornadoes form in a certain quadrant (the southeast) of the low area which they attend.

The reason for this is found in the fact that this quadrant is the great heat and moisture region of the low, and where the

circulation of the warm moist air, underneath the cold, anticyclonic air currents from the north, gives rise to the development of unstable equilibrium.

Not only is the southeast quadrant the tornadic region of the low, but it is also the region which gives birth to all violent local storms. All such disturbances depend upon unstable equilibrium as the initiatory force.

The results of the study of tornado maps may be briefly summarized as follows:

1. That the tornado region is not coincident with the area of lowest pressure.
2. The tornado region is confined to the SE quadrant of the low.
3. The tornado region is several hundred miles southeastward from the general storm centre.
4. The SE quadrant is the region of greatest heat and moisture in the low. As to moisture, the NE quadrant is also prominent.
5. The SE quadrant is the local storm region of the low.
6. The local storm region is within the belt of southerly winds.
7. The line of separation between northerly and southerly winds approximately marks the limit of precipitation to the east and west.
8. The area of precipitation moves eastward with this line.
9. That along this line, on both sides of it, the heaviest precipitation generally occurs, and also some of the heaviest winds.
10. The average wind velocity is generally highest in the SW and NW quadrants, followed next in order by the SE quadrant.
11. The highest wind velocities (25 miles per hour and upward) occur in the SW quadrant, where they are also the most frequent.
12. The SE quadrant stands next in order to the SW quadrant for maximum wind velocities, both in number and degree.
13. The NW quadrant stands third in order, followed by the NE quadrant with no maximum velocities.
14. The maximum velocities are principally confined to the latter half of the day, especially in the SE quadrant.
15. As the low approaches the meridian of the tornado region the southerly winds gradually increase in velocity, the isotherms curve more to the north, the moisture increases and the dew point rises.

16. In the morning the highest wind velocities in the SE quadrant are near the center of the low, and during the afternoon and evening, near the center of the tornado region.

17. In the SW quadrant the highest wind velocities are most distant from the centre of the low in the morning, thereafter gradually drawing nearer, reaching the nearest point in the evening.

18. In the NW quadrant the conditions are similar to those in the SW quadrant, except that the highest velocities are nearer the centre of the low.

19. The wind velocities in the NE are not particularly significant.

20. The wind velocities here referred to appear to have important connection with the tornado region, especially those occurring in the SW and SE quadrants.

21. The apex of the curve of high temperature is much nearer the centre of the low than the apex of the curve of low temperature.

22. The tornado region does not coincide with the region of the highest temperature gradient, as shown by the surface observations, but lies to the south and east of it several hundred miles, being nearest about noon, and most distant about sundown.

23. There are two regions of marked temperature gradient, the most decided lying between the northern portion of the SE quadrant and the southern portion of the NW quadrant, the other region lying between the northern portion of the SW quadrant and the southern portion of the SE quadrant.

24. The tornado region (in the particular case under consideration) lies nearest the southern temperatnre gradient region.

25. In some cases the tornado region lies about half way between the two temperature gradient regions, and sometimes nearer the northern one, yet more frequently nearest the southern region.

26. As practically the whole of the SE quadrant of the low is subject to unstable equilibrium it is rather difficult to say just where the most decided conditions will manifest themselves. In this connection it must be borne in mind that all violent local storms result from unstable equilibrium, and that the hailstorm is a tornado above the surface of the ground.

27. As the unstable equilibrium which gives rise to a tornado appears to first manifest its force in the cloud region, where the

whirl always starts, it is not strange that the surface observations frequently fail to show a direct connection therewith.

The tornado is there, and, with the aid of both local and telegraphic stations properly distributed, the weather chart may be able to furnish the desired information for prognostication.

Observations at considerable heights, from captive balloons, may prove very useful in this connection.

The Tornado's Appearance.—The great moisture of the air in the southerly winds of the SE quadrant is especially favorable to the induction of the unstable state, since such a change is more readily brought about in air nearly or quite saturated.

The visible effect of the unstable state is first observed in the cloud region by the appearance, in the west and northwest, of a heavy and portentous bank of clouds, followed suddenly by a violent commotion on the face of the dense black mass, and the rushing of adjacent clouds toward the centre of disturbance, especially from the southeast, east and northeast.

The observer, watching this aerial contest, finds himself in a region of gentle, southerly, heated air currents.

Quite frequently there is a dead calm, oppressive heat and ominous silence, followed almost immediately by the deadly swirl of the funnel-shaped cloud and the cold westerly blast in its wake, that has so many times chilled to the marrow the mangled victims of the tornado's fury.

The violent whirling motion of the air which characterizes the tornado is, as has been frequently referred to, dependent upon a pre-existing disturbed and gyrating state of the atmosphere.

Sometimes, long before the effect of its characteristic whirl is felt upon the earth, the evidence of the tornado's ominous presence is denoted by the appearance of a peculiar cone-shaped mass of cloud, suspended against a threatening sky, indicating the descent towards the earth of the centripetal motion in the air.

The outward semblance of this motion may assume a variety of modifications of the inverted cone, but the variations are not such as to confuse the observer, or make him uncertain of what to expect.

Of course while the portentous cloud soars far above the earth its violence is not experienced by the denizens thereof and some may say that, during this stage of the storm's existence, it can not be properly termed a tornado.

There is reason in this criticism, if it is meant that complete development has not yet been attained, and that the full-fledged tornado must extend its whirling vortex of air to the earth's surface and thrash the ground with its tail.

Tornadoes may appear after sundown when the peculiar form of the cloud can not be distinguished, and in such cases the path of destruction wrought upon the earth must be examined to determine the evidence of the spirally inward whirl of the vortex currents, and therefore the presence of the funnel-shaped cloud.

It frequently happens that the tornado cloud rises from the earth and forms a gap of several miles in its path, descending again with its usual violence, to remain, perhaps, until it finally disappears.

If an observer is located in the gap and witnesses the tornado cloud passing overhead at a safe distance he should, according to some critics, report no tornado, unless perchance he examined the entire track of the storm, which he is not at all likely to do, as one who voluntarily renders service for science.

If reports can be obtained from various points along the supposed track of the storm, its identity may be established by unmistakable evidence of its violence.

It may be said, however, that neither the form of the cloud alone nor the evidence of peculiarly disposed debris should be taken as positively deciding the existence of the tornado at the place of observation or along a supposed track.

The tornado should not be located without a combination of facts which are known to depend upon, and show, the very conditions of tornadic formation.

Where and When Developed.—The question naturally occurs where are the places on the earth's surface and what is the time when conditions are most favorable for the development of tornadoes?

First. As to places: These are found in regions where warm moist air begins to flow underneath colder and drier upper strata coming from another direction, followed shortly by an inversion of the air in the upper and lower strata, by which the colder denser air finally replaces, at the earth's surface, that which is warmer, lighter and more humid.

The moment of this change marks the incipiency of tornadic development.

Geographically and topographically considered, the Lower

Missouri, Central Mississippi and Ohio valleys present conditions most favorable for the generation of tornadoes.

Second. As to time: The summer season is most favorable for tornadoes, when the interior of the continent is warmed up and the air of the lower strata is drawn from lower latitudes far up into the northern portions of the country, on the eastern side of the Rocky Mountains, and the isothermal curve is deflected very decidedly toward the north.

Local Signs of Tornado Formation.—1. The prevalence of southerly winds with a gradual but continued increase of heat and moisture.

2. A sultry and extremely oppressive condition of the atmosphere, which is sometimes characterized as "sticky," or so quiet as to call forth the remark that "there is not a breath of air stirring."

3. The form, color, motion, character of development and place of formation of clouds. The sudden appearance of ominous clouds, first in the southwest, and then almost immediately in the northwest and north, is sufficient to attract the attention of the most casual observer.

4. In nearly all instances, these premonitory clouds are unlike the ordinary formation which signifies rain and perhaps a thunder-storm. If the clouds are light, they resemble smoke rising from a burning building; if dark, they present a deep greenish hue which appears to increase in intensity as the storm advances. Sometimes these dark clouds appear as densely black masses of smoke rolling upward from the chimney of an engine.

The motions of the clouds are peculiar in that they appear to be rushing from every quarter towards a common centre, marking the incipient stages of a gyratory motion in the cloud region.

Local Signs of Tornado's Approach.—1. The tornado cloud is of course not visible from all directions while sweeping the earth. The limit of vision is necessarily greater in some cases than in others, depending upon the topography of the intervening country.

2. Where the funnel cloud cannot be seen, its existence can readily be distinguished by the peculiar roaring noise which is likened to the rumbling of distant thunder, or the approach of a heavy train of cars. The noise is said to resemble the "sighing of the wind through a forest."

3. As the storm approaches nearer, the sound increases in intensity until the final crash of the elements, which comes with

the suddenness of an explosion. The noise is sufficiently peculiar and distinct to create alarm, and as a means of warning, must not be ignored.

4. A few moments before the assault there is a death-like stillness in the air. The observer's eye catches the absence of any movement in the leaves upon the trees, which a moment before danced in a gentle wind. The ominous silence portends grave results and requires that no time be lost in seeking the most perfect means of safety.

General Results of Investigation Based on Reports for over 200 Years.—1. Tornadoes very generally accompany a low, for the reason that the condition of unstable equilibrium necessary in the formation of a tornado is also required in the low, at least in the cloud region.

2. The progressive motion of tornadoes to the northeast arises from the fact that, as they always form in the southeast quadrant of an area of low barometer, they must come within and under the influence of the general drift of the atmosphere on that side of the low, which according to the law of atmospheric circulation about the centre of an area of low pressure, is always to the northeast.

3. The unstable state in a low does not always extend down to the earth's surface, so that tornadoes are not necessarily visible in every general storm.

4. There are frequently secondary whirls, incipient tornadoes, in the cloud region of a low, the effects of which do not reach down to the earth's surface, and the only visible effect above is the formation of a local cloud a little denser and darker than the clouds are generally.

5. A hailstorm is an incipient tornado in the cloud region of a low.

6. Tornadoes always occur in the southeast quadrant of a low and at distances generally of 300 to 500 miles from the centre of it.

7. As the low progresses eastward, the region of country lying, on the average, about 350 miles to the south and east of the centre of the general storm at any time, is the region within which tornadoes may be expected.

8. The greatest destructive violence of a tornado is sometimes confined to a path a few yards in width, or it may widen to the extreme limit of eighty rods.

9. The tornado, with hardly an exception, occurs in the after-

noon, just after the hottest part of the day. The hours of greatest frequency are 3:30 to 4 P. M. and 4:30 to 5 P. M.

10. The destructive power of the wind increases rapidly from the circumference of the storm to its centre.

11. The tornado season includes the months of March, April, May, June, July, August and September, but storms of this nature may occur in any month of the year. The months of greatest frequency, as determined from a record of 206 years, are April, May, June and July. The month of greatest frequency is May, April coming next on the list.

12. The state in which the greatest number of tornadoes have occurred is Missouri, followed next in order by Kansas and Georgia. The 425 tornadoes and "windfalls" recorded in Wisconsin far exceeds the number in any other state, but little weight can be given this fact, owing to the want of similar investigation of the subject of "windfalls" in other states.

13. Considering the entire record of eighty-eight years (years of record from 1682 to 1888) nearly 4,000 persons have been reported killed and 6,000 injured. The record is very imperfect, owing to the large number of cases in which the killed and wounded were not definitely reported.

14. Considerng the reported valuation of property destroyed, the following states have experienced the most destructive storms, and in the order named: Missouri, $94,325,000 in forty-seven years; Ohio, $87,737,500 in eighty-four years; New York, $67,000,000 in one hundred years; Kansas, $64,000,000 in twenty-nine years; Georgia, $56,500,000 in ninety-three years; Minnesota, $50,750,000 in thirty-three years; Iowa, $49,575,000 in forty-five years; South Carolina, $46,875,000 in one hundred and twenty-seven years. These values are necessarily approximate, owing to imperfect reports, and it is believed that they fall considerably short of the actual amount of loss.

15. From a careful investigation of the origin of tornadoes and their geographical distribution there is every reason to believe that these storms were as frequent and violent two hundred years ago as now. Moreover, there appears to be no cause for any unusual change in the annual frequency of tornadoes for a like period to come.

16. The years (118) that are missing in the period of 206 years, from 1682 to 1887 inclusive, are not to be considered as years in which no tornadoes occurred, but as years in which records are wanting, owing to failure of observations.

Considering the past ten years (1878 to 1887 inclusive) as furnishing reliable and exhaustive records of tornadoes, and that the period prior to 1878, (196 years, 1682 to 1877 inclusive) is deficient, owing to want of facilities in collecting reports, we may give an interpolated value for each of these latter years, as determined from the complete ten-year record. This value is found to be 146, which means that on the average 146 tornadoes will occur yearly in the United States. Applying this constant to existing records we have a grand total of storms from 1682 to 1887 inclusive (206 years) of 30,076 tornadoes, instead of 2,435 actually observed and reported. This would indicate a failure to report the occurrence of about 27,641 tornadoes which have probably passed over portions of this country since 1682. In that year a very destructive tornado with distinct funnel-shaped cloud visited New Haven, Connecticut, at 2:30 P. M. on the 10th of June.

17. No well authenticated case of a tornado has been reported from the region of country lying west of the 105th meridian, and it may be generally stated that these storms do not occur in the United States west of the 100th meridian. The cause for this is found in the lack of favorable conditions, on account of the dryness and the lower temperature of the air, and the want of uniformity in the direction and force of surface currents.

Violent straight winds attended with considerable destruction to property have been reported several times in the past fifteen years, from southern and central California, Arizona, New Mexico and Montana.

18. By comparing the number of tornadoes in each state with the acreage of forests, as estimated in the last census report, it is found that the latter appear to have no perceptible influence in preventing the occurrence of tornadoes, or in assuaging their violence.

19. The width of the path of destruction, as determined from the records of 88 years, varies from 10 to 10,560 feet, the average being 1,369 feet.

20. The length of the tornado track varies from 300 yards to about 200 miles, the average being 24.79 miles.

21. The velocity of progression of the tornado cloud varies from 7 to 100 miles per hour, the average being 44.11 miles. These extremes may often occur in different portions of the track of a single tornado.

22. The shortest time occupied by the tornado cloud in pass-

ing a given point varies from an "instant" to about 20 minutes, the average being about 74 seconds.

23. The prevailing direction of the progressive movement of the tornado cloud is northeast.

24. The vortex wind velocities of the tornado cloud vary from 100 to 500 miles per hour, as deduced from approximate measurements. Velocities of from 800 to 1,000 miles per hour are extremes that have been reported, but the data are not reliable.

25. The cloud generated by the vortex assumes the form of a funnel with the smallest end towards the earth. This explains the remarkable contraction of the storm's path. Upon reaching the earth's surface, the vortex has four motions, viz.: First. The whirling or gyratory motion always from right to left; Second. The progressive motion, generally from some point in the southwest quadrant to some point in the northeast quadrant; Third. The curvilinear motion; Fourth. The oscillatory motion.

26. Windfalls are the tracks of tornadoes through forests as shown by the prostrated and confused masses of timber. In many cases there remain but the skeletons of these ruins and their location is known only to Indians, trappers, hunters and surveyors.

There is not a state east of the Rocky Mountains that has escaped these serrated tracks through its forests and the record of their occurrence will in many cases be found upon the plats of the early state surveys. Windfalls both of recent and very early date are still to be found in the forests east of the Mississippi.

Protection to Life.—27. The south side is the dangerous portion of the tornado; the north side is the safe portion.

28. If the cloud is moving to the northeast, then the line of escape is to the northwest, if to the east, then to the north. Stand facing the advancing cloud in the direct line of its approach and the safe side is always to the right.

29. No structure that rises above the earth, however made, can wholly resist the violence of the tornado, and therefore no building is safe as property or as a resort to protect life.

30. Under all circumstances, as precaution against danger, whether in a building or in a cellar, refrain from taking a position in a northeast room, in a northeast corner, in an east room or against an east wall.

31. In the open country one should never undertake to escape from a tornado cloud without first making sure of the points of

the compass, and that the direction to be taken is in a line at right angles to the path of the advancing cloud.

32. To make escape certain the tornado cloud should not be less than three-fourths of a mile distant, which gives the observer a momentary chance to ascertain the character of motion it possesses, the velocity of progression, the width of the path and the points of compass.

33. A frame building is safer than one built of brick or stone. The former is more elastic and holds together longer. The latter goes down in the first crash and the debris is whirled into a heap in the centre of the foundation.

34. In a frame structure the safest place is in the cellar but in a brick or stone structure it is the most dangerous.

35. The tornado cave offers absolute security to life and limb and nothing can replace it for that purpose. This retreat may be constructed either as a cellar-cave or as a dug-out.

36. As offering a certain measure of protection in tornado districts, a tornado accident insurance policy might be carried for the tornado season, especially by those people who, from the exigencies of business or other imperative duties, are unable to employ other and better means of protection.

Protection of Property.—37. No building can be made sufficiently large, strong, high or low, or of any material whatever to resist the force of the tornado's vortex.

38. It is impossible to change the path of the tornado by the employment of explosives or any artificial barrier.

39. It is idle to contemplate the dispersion of the cloud by the use of any electrical or other contrivance. The tornado has come to stay, and will remain as long as the earth has an atmosphere and the sun shines upon it.

40. Construct all buildings without reference to the tornado, but protect them, not by a "tornado lightning rod" which is supposed, in some mysterious and effective manner, to draw off safely the fierce venom of the storm, or by the use of a "tornado bomb" to scatter the wild fury of the funnel shaped cloud, but by the employment of some reasonable and efficacious means that will secure an adequate return for the loss sustained.

41. It is idle prattle to talk about the ultimate disappearance of the tornado with the rapid development of the country. The building of railroads, the planting of forests and the cultivation of the land are all evidences of material prosperity, but are not in the least conducive to the disappearance of conditions favor-

able to the development of tornadoes. On the contrary they provide greater opportunities for exhibitions of their violence.

42. From a business view, and as affecting the question of life and property the tornado must be considered as one of nature's agencies for destruction which must forever be fortified against. Like fire and flood, but yet more dreadful, protection against such forces must be accomplished by organized capital where the safety of one is assured by the legitimate and successful co-operation of many.

43. Protect chattel property, as far as possible, by the tornado cave and all other property by tornado insurance.

Tornado Prognostication.—To forecast successfully the time, place and direction of movement of any atmospheric disturbance is a difficult matter, and it may be stated generally that the measure of success will vary, within certain limits, according to the area of country under the influence of the particular disturbance; the greater the area the greater the probability of success.

There are many elements which enter into the prediction that render the problem, except under the most favorable circumstances, an extremely complicated one, especially where great accuracy of results is demanded.

It is well known that the tornado has the most circumscribed area of all storms, while its violence has no equal in the entire range of meteorological phenomena.

The prognosticator has not only to contend with the difficulties of contracted area, sudden development and peculiar isolation, but the very annoying failure of the weather map to show the actual local changes at the place of probable tornado development. Stations on the weather map are necessarily widely separated, geographically, and the predicter must make up for this loss of important local information by experience, and the acquirement of expert knowledge, as to the interpretation of general indications, which, as has been already shown, are strongly marked and reliable.

The general indications here referred to comprise the general characteristics of tornado development and the relation of tornado regions to areas of low pressure, all of which may be briefly summarized as follows:

1. The presence of a well defined area of low pressure; marked barometric gradient not necessary.
2. Slow progressive movement of the low in order to increase

the flow northward of heat and moisture in the SE quadrant.

3. A trough-like low trending north and south, or northeast and southwest.

4. The descent of a well marked anticyclone in rear of the low.

5. High temperature gradients.

6. The increasing wind velocities of the SE, SW and NW quadrants of the low.

7. The northward curve of the isotherms in the SE quadrant and the eastern portion of the SW quadrant of the low.

8. The southward curve of the isotherms in the NW quadrant and the northern portion of the SW quadrant.

9. The high temperature gradient between the apices of the opposing curves of temperature.

10. The increasing and uniformly high humidity of the SE quadrant.

11. A knowledge of the areas of maximum tornado frequency for each state.

12. A knowledge of the occurrence of tornadoes in certain regions of the country, in certain months of the year.

13. A knowledge that tornadoes frequently occur in groups having parallel paths of progression, within a few miles of each other.

14. A knowledge that tornadoes always form in the SE quadrant of a low several hundred miles southeast of its centre.

15. The easterly curve in the SW and NW quadrants of the line separating the northerly and southerly surface currents of the low.

Conclusions.—The writer is of the opinion that the forecasting of conditions favorable to the development of tornadoes and designating the quadrant of a state in which such conditions shall give rise to local signs that the inhabitants of that section can rely upon, is entirely practicable. By this admission he does not mean to convey the idea that the exact path of the funnel-shaped cloud can be indicated in the dispatch, for that would be impossible except by chance. The average width of the tornado's track is only a few hundred yards, and several of these storms may occur in the same county, with entirely independent paths of destruction and distinct cloud formation.

It doubtless appears that the quadrant of a state, especially the larger ones, is a very extensive area to cover with a single tornado prediction, but the fact must not be overlooked, that

where the conditions are favorable for tornadoes, local storms having various degrees of tornado violence, the development of which it is very important to herald, occur here and there over a large section of country. Therefore, the scheme of local storm predictions for state quadrants would seem to possess the elements of success, for, while the peculiar funnel-shaped cloud might not appear, the conditions are such that local storms of great violence would very likely occur, and destruction to life and property ensue. Although of course the area here indicated (state quadrants) is quite variable in extent, yet it possesses the decided advantages of definiteness, familiarity to the people who are interested, and brevity of expression in rendering a concise dispatch. The local signs of tornado development are certain, easily observed and well defined. With the people well informed concerning these indications, and there appears no reason why they should not be, the prediction of conditions favorable for local storms, issued from some central meteorological office, would, if successful, supplement the local signs with beneficial results. Failures in the official predictions would not only bring out more distinctly the importance and reliability of local signs, thus creating an interest in their careful observance, but would obviate the occurrence of serious results when wrong predictions were made, inasmuch as the people would test their trustworthiness by an appeal to the local signs.

TORNADOES. SECOND PRIZE ESSAY.

BY A. McADIE.
Fellow at Clark University.

The Chief Signal Officer in the annual report for 1887,* takes this very conservative position, the practicability of predicting tornadoes. "The Chief Signal Officer feels that neither the "present condition of the science of meteorology, nor the practical needs of the country, would justify such forecasts. So "almost infinitesimal is the area covered by the line of tornado "in comparison with the area of the state in which it occurs, "that even could the Indications Officer say with absolute certainty that a tornado would occur in any particular state or "even county, it is believed that the harm done by such a prediction, would eventually be greater than that which results

* Page 22.

"from the tornado itself. The Service goes as far as is deemed "proper in predicting from time to time *that conditions are* "*favorable for severe local storms.*" *

Before proceeding to the discussion of our knowledge of the tornado, which of right should precede any argument as to the propriety and necessity of prediction, we may, none the less, be allowed to question the reasoning of the paragraph quoted. † If the acquisition of knowledge is one of the prime aims of existence, we must not defer its pursuit because of a fear of the consequences ensuing, due to ignorance! Nor can the commotion and alarm of a community, fearful of misdirected prediction, be fairly weighed against the benefits and advantages to a community warned of the likelihood of a tornado, in that section or county, within a given time! And, yet further, has the Indications Officer the right to cloak under the term, "severe local storms" ‡ the possibility of a "tornado," leaving the section for which the prediction was made, to these very terrors of imagination, hinted at, as valid reasons for not giving a concise and definite statement of the danger likely to occur! The forces brought into action in "severe local storms" may be met and opposed—successfully—as far as the elements of destructiveness to life and property is concerned; but the forces developed in the progress of the tornado, are not comparable with those we would offer in opposition. An example will illustrate the difference. What will be the force of the wind upon the wall of an ordinary dwelling house, say 25 feet high and 40 feet long? The pressure of the wind is as the square of the velocity, and also as the density of the air. The formula §

$$p = \frac{s^2}{151.7\,(1 + .004\,T)}\;\frac{P}{P_0}\,S$$

gives us p, the pressure in grams; s, the velocity of the air; P, the observed barometric pressure; P_0 the standard pressure; S, the area of surface exposed, in square centimeters; $(1+.004\,T)$ co-efficient of expansion of air in ordinary hygrometric condition; and which multiplied by the factor 151.7 and $\frac{P}{P_0}$ approximately represents the density of the air. From this

* Italics mine.

† The writer expressly disclaims any intention of criticism of the Signal Service, and here and elsewhere merely asserts his right to differ from published opinions.

‡ Ferrel (20) page 302.

§ Ferrel (20) page 302.

we shall find that the pressure in grams per square centimeter upon our wall, if normal to the direction of the wind, would be, for a wind of fifty miles per hour velocity, approximately 3 grams per square centimeter; and as our wall is 1000 square feet or approximately 925,000 square centimeters we should have a total pressure exerted upon the wall of about 2,775,000 grams or 2,775 kilograms, which we may call roughly a pressure of over 5 pounds to the square foot, or a total pressure of something like 5,000 pounds. For wind velocities of about 100 miles per hour, the pressure would not be simply doubled to about 10 pounds per square foot, but more nearly three times this, or about 30 pounds. If we take a velocity of 300 miles per hour—and this does not seem an extravagant estimate;—(according to Finley, the vortex wind velocities of tornado cloud vary from 100 to 500 miles per hour—as deduced from actual measurement*)—we have a pressure of approximately 120 grams per square centimetre, or nearly 250 pounds per square foot, or a total pressure on the supposed wall of 250,000 pounds. In other words, concerning the force components that have a destructive effect on standing walls, buildings, etc., if we represent the efficiency of those developed in a "*severe local storm*," by 1, we should represent those developed by a tornado, by 50, *at least*, for in our estimate, we have considered only effects due to the enormous increase of wind-velocity, and undoubtedly there are other factors, destructive in their operation.

For this and other reasons, we think, that the terms, "*local storm*" "*tornado*," (and "*cyclone*,") should be used with discrimination, especially at this time, when the tendency is so marked to use all storm-type names, synonymously.

We propose in this paper to discuss, 1st, *the nature and general characteristics of a tornado;* 2d, *the possibility and practicability of predicting tornadoes.*

Under the first head, we may call all motions of the atmosphere due to a condition of unstable equilibrium of the atmosphere, and in which the initial motion is due to a difference in temperature, *cyclones.*

Different types of storm embraced under the generic term cyclones, are

A. Proper cyclones, or large cyclonic movements of the atmosphere as distinguished from the general circulation;

* Reference given further on.

B. Sub-cyclonic storms; the tornado, water-spout, hail-storm and thunder-squall.

The points of difference and resemblance between these classes may be summed up as follows:

Cyclone proper differs from tornado,

a. In extent;

b. The increase of temperature in certain parts, arises less from the energy of the storm itself, than from extraneous causes; *i. e.* although much heat may be evolved by the process of condensation and convection, and from the storm's mechanical energy, these act effectively only after the development of the storm. The initial increase of temperature was probably due to the warming up of some large area by the direct heat of the sun, or the introduction of cold or chilled air currents of large extent.

c. The gyratory motion* "depends upon the effect of the earth's rotation, and may be, and generally is, sensibly independent of any initial motion of the atmosphere relatively to the earth's surface."

I. The effect of friction † of air against earth surface is, in a mathematical discussion of the motions of the air particles, quite apparent. Naturally so, when we remember that the "cyclone proper" is treated of as a broad thin "sink" of revolving air.

II. Tornado differs from a cyclone in

a. Extent of territory affected by it, the area being confined and compared with that of a cyclone proper, small.

b. In its "structure" (if we may use the term); being a column of air with base small in comparison with its altitude.

c. The gyratory motion depends on, or rather is determined less by, the earth's rotational effect, than by some local "strongly-acting" cause.

d. The frictional effects are less marked, as the surface exposed is so much smaller, though of course, the increased velocity augments the friction.

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* "Recent Advances in Meteorology," by Professor William Ferrel, Chapter V, page 287.

† *Effect of Friction.*—The linear gyratory velocity due to the earth's rotation, of any point of the earth's surface (as given by Ferrel, page 289) is 0.18 mile per hour at the parallel of 45°, at a distance of one mile from the centre. In the case of ordinary tornadoes, in which the distance is much less than a mile, the linear gyratory velocity per hour is small and may be neglected in comparison with the usual velocities in a tornado which may average 150 miles per hour. In the ordinary cyclone, however, the distance one mile becomes perhaps 250, and hence correspondingly greater frictional effects may be looked for.

III. Tornado resembles cyclone proper in

a. It has its origin in the condition of unstable equilibrium of the atmosphere.

b. It has (according to Professor Ferrel)* "the same interchanging motion of atmosphere between central and exterior parts."

To sum up, then; cyclones proper in structure are broad thin "sinks" of revolving air, with "a central calm, a strong oblique cyclonic inflow around the centre, a peri-cyclonic calm and faint exterior oblique outflow, all of which are best developed at the surface, and disappear or are reversed above;"† the tornado, a secondary "*whirl*," in which at least four component motions may be noticed, an influx to the vortex from all parts, with a progressive motion to the northeast, and "always formed in the southeast quadrant of an area of low barometer."‡

We have classified above hail-storms, water-spouts and thunder-squalls with the tornado, as a type of storm, and it is necessary at this point, therefore, to discuss briefly their relation to the tornado. As yet, we barely know more about these storms than the distinguishing features. They are all storms of comparatively small area and great intensity. They might be called "sub-cyclonic" or "secondary" storms brought about by the cyclone proper, and having a definite relation to the center of the larger storm, or as it is generally named, the storm-center. Of the particular "mechanism" and "construction" of each class, unfortunately we know yet but little, and the different causes at work we do not clearly comprehend. With regard to thunder-squalls we know that they occur in the southeast quadrants of "lows," follow the higher winds in their motions about the storm-center, rather than the surface winds, and in northern latitudes "advance to the east when they arise to the south of "a pronounced center of low pressure; to the west when they "appear to the north of these centers, though this last case is "infrequent."§ "The winds are found to obey Buys-Ballot's law "*i. e.*, they flow obliquely to the right, down gradients;—and, "the clouds move in various directions."‖ According to Von Be-

*Chap. V, p. 287. "Recent Advances in Meteorology."

†Wm. M. Davis: "Classification of Winds." AMERICAN METEOROLOGICAL JOURNAL, January, 1887, p. 516.

‡J. P. Finley: "Character of Six Hundred Tornadoes."

§AMERICAN METEOROLOGICAL JOURNAL, 1886, p. 498. W. M. Davis: "Foreign Studies of Thunder-storms."

‖Ibid.

"zold* thunder-storms are especially frequent in the 'saddle' "of high pressure between two adjacent low pressure areas. . . . "Just in front of the storm-band the pressure suddenly increases "and the temperature suddenly falls; so that the front margin "of the storm separates a region of lower pressure and higher "temperature from one of higher pressure and lower tempera-"ture, the latter being within or behind the storm."

Systematic observations of thunder-storms, made in different countries, give further evidence of the relation of these storms to the larger cyclonic disturbances. Thus, in a study of the thunder-storms of Russia made by Klossovsky,† it appears, that these storms occur generally in the SE quadrant of a cyclonic area, and are absent in "anti-cyclonic" areas. "Thunder-"storms of moderate intensity sometimes occur when the at-"mospheric pressure is nearly uniform over a large region; but "in such cases the bending of the isobars indicates *that the* "*storms are connected with small secondary depressions.*"‡ "It is also clear that thunder-storms are most frequent on the "marginal parts of cyclones, on the frontier between maxima "and minima of pressure." "Thunder-storms are in fact small "cyclones originating in the segmentation of the larger storms "in the peripheral parts, each segment moving as a whole in "accordance with the larger cyclonic circulation." § As in Russia, so elsewhere;—systematic studies of thunder-storms show this agreement as regards distribution. Other questions, as for example "the vertical decrease of temperature before and during storms," ‖ the various wind movements, and cloud developments as well as cloud motions, will soon now be brought into discussion. Hail-storms agree closely with thunder-storms, as regards distribution and the features of temperature and pressure changes, and wind movement. Apparently, thunder-storms and hail-storms are storms similar to tornadoes, and closely related in formation.

The other type of storm, belonging to the general class, with tornadoes, is that known as "water-spout." The literature of mere description of water-spouts, fair-weather whirlwinds and "white squalls" is well nigh inexhaustible, and could be ex-

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* *Austrian Meteorological Journal*, August, 1883. Reference taken from Davis as above.

† W. M. Davis: "Studies of Foreign Thunder-storms." AMERICAN METEOROLOGICAL JOURNAL, 1886, page 43.

‡ Davis as above. Italics mine.

§ As before, page 45.

‖ Davis, page 43.

tensively quoted from; but we propose to give but one example, and we select this, because it is perhaps the latest description, and is besides a case in which the observer came prepared to watch and was free from anxiety or fear of danger.

"On Tuesday September 4th, 1888,* a fine water-spout† was "projected from the level vapor-plane of a silvery-edged tower-"ing cumulus cloud,—or as our American cousins would term "it, a "thunder-head"—which by the aid of a good telescope "showed well the down rush on the inside of the tube and its "counterpart, the whirling up-rush on the outside, twisting and "coiling round and round against the watch hands (face up-"wards). The day had been close, hot and breezeless, so far as "the surface was concerned, and the cloud in question formed "a grateful screen to the afternoon's sun." . . . . "At about "5 P. M. a well formed water-spout was observed trailing away "northeastward,‡ from the cloud's northern verge, then about "40° or 30° high. Near the dense cloud from which it grew, "its mass was dark and opaque, but from half-way down its "length, to below where it terminated in an unfinished turmoil "of jags and rags, it was semi-transparent, the clouds beyond in "the back ground being distinctly seen through it, and there was "a light colored tube within its gauzy mass, which at times was "very pronounced and conspicuous. *There seemed to be no "commotion on the river, or the shore,*§ over which its lower "part hung at a height of 500 or 600 feet, from the time when "it was first observed until it began to wane and draw itself up-"wards. It was when it had shrunk and shortened that the "inside down rush was seen to advantage, and the simultaneous "upward whirl around the dense remains of the tube, which so "far as I was able to make out from the motions of the cloud-"lets, I cannot do better than liken to the turning inside out of "a coat sleeve, or of a stocking, only the *end of the tube was "always ragged,*§ and here where the reversing process was "taking place, there was great commotion in the air currents, "more especially after the tube had withdrawn itself up to its "opaque head. I had a good telescope, observed these phe-"nomena very carefully, and was on the alert for optical illusion, "and as the upper part of the spout remained intact for a long

* Account given by S. R. Elson, printed in the *Englishman*, Sept. 13, 1888, and reprinted in *Nature*, January 31, 1889.

† Rather a "fair-weather whirlwind" or "small tornado."

‡ Mouth of Hughli River—Bay of Bengal.

§ Italics mine, to illustrate second proposition on next page.

"time after the gossamer-like lower continuation had melted "into invisible vapor, I had an opportunity of studying it well. "The thunder-headed cloud from the lower part of which the "spout issued, gradually melted away and grew less gaudy as it "dwindled, without as is usual under similar circumstances "pouring forth a torrent of rain. But there was a double rain-"bow projected on the clouds banking up over to the eastward, "and evidently rain was falling in the space between them and "the sun for some time after the last remains of the spout had "disappeared."

This account, like many others, makes us emphasize the following points:

First, all these storms, having a tornadic action, are creations of the moment, so to speak; and the conditions always found to prevail during their occurrence, if varying but slightly, may occur and re-occur, without the development of these storms.

Second, we may not always be able to discern the existence of these storms. There are undoubtedly many "whirls," "incipient tornadoes," and "gyrating clouds" that pass harmlessly and unnoticed over our heads. If the quantity of water vapor in the air, at some given place, is not large, the condensation of it might not result in a cloud form that would excite our notice; or furthermore, the condensation might have taken place at such an altitude that the whirling motion of the air could not influence it sufficiently to bring the cloud thus formed down to the earth or sea surface.

Third, the barometer does not necessarily give warning of the proximity of these storms. This has been observed to be the case where a ship has sailed into a water-spout in process of formation, (and nothing in the way of a cloud or condensed vapor affording warning), with the barometer until the actual presence, almost of the storm, remaining unaffected.* At, or very close to the centre of the storms, the diminution of pressure is marked; and objects then experience not only the strong in-flowing, whirling and out-throwing forces, but also the destructive explosive forces, caused by the expansive action of the air confined within them.

So much has been said *with so little authority*, of electricity and the part it may play in connection with the development of the tornadic storm, that we hesitate here to make even a sug-

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*Case of the British bark *Belle Stuart*, 160 miles from Cape Sable, Nov. 14, 1878. See Ferrel, p. 321.

gestion, though of a very different nature from those generally made. Our suggestion is that a future important use possibly awaits the *electrometer* (as used in the study of atmospheric electricity) as an instrument better adapted than any in present use, to give notice and warning of the proximity of violent whirlings in the air. As we have seen, the barometer is too sluggish and the thermometric indications too much masked, to be serviceable. Besides it is questionable if the transmission of the pressure disturbance or the propagation of heat waves (meaning thereby, temperature changes) are very sensitive methods. We have found out from electrometer work, although yet but in its beginning, that by those peculiar properties appropriate to electricity, disturbances such as snowstorms, rainstorms, thunderstorms, give certain indications on electrometers far distant. Nothing has been done yet with these instruments in connection with the study of tornadoes; but without question, if these rapid whirlings, by friction, by inductive influences, or in ways not yet understood, bring about electrical effects (as it seems all too evident they do), we know enough to say that it is within our power to study these storms *at a distance;* and what is of the utmost importance, to detect those which would otherwise pass unheeded.

Fourth, as will be developed further on in this paper, perhaps the method which promises most in the way of obtaining knowledge bearing on the occurrence of tornadoes, is that of a careful study of cloud movement. Perhaps we shall detect many a tornado, and embryo tornado, in the "whirling" of cloud masses; and at least we shall have more light upon one of the principal conditions controlling tornado occurrence, viz.: "The state of "unstable equilibrium of the atmosphere." The matter of careful cloud study has not received the attention it merits, and it is time for a protest against directing our entire search for a better knowledge of meteorological phenomena to the borderland of their domain, rather than to the very home and seat of their occurrence.

From the studies that have been made of tornadoes, the following facts seem established beyond doubt:

First, two conditions must exist for the occurrence of a tornado,

a. A state of unstable equilibrium of the air;

b. A gyratory motion around some centre.

A third condition that naturally follows is that some local dis-

turbance shall "cause the air to burst up at some point through "the strata above."*

Second, in northern latitudes tornadoes are always formed in the *southeast* quadrant of a cyclone proper,—as we have seen is the case with thunder-storms, hail-storms, and all those types of secondary storms. Naturally, from their relations to these larger disturbances, we should expect to find that the general progressive motion of these storms is *northeasterly*.

Third, tornadoes are not necessarily visible.

Fourth, their general distribution (statistics deal only however with those in which the tornadic action has extended downward to the earth-surface) depends on the more general movements of the atmosphere, as determined by geographical conditions.

The following more specific facts have been obtained from the studies of the Signal Office, and are given by Finley† in his "Character of Six Hundred Tornadoes":

a. "The places and times most favorable to the development "of unstable equilibrium and a gyratory motion of the atmos-"phere, are those in which tornadoes are most likely to occur." . . . "Where warm, moist air flows underneath colder and "dryer upper strata coming from another direction. Such "regions are found particularly in the Mississippi, Missouri, "and Ohio valleys, and in Alabama, Georgia, and the Carolinas."

b. "The month of greatest frequency is May."

c. "Shortest time occupied by the tornado cloud in passing a "given point varies from an instant (?) to about twenty minutes. "The average time is seventy-four seconds";

d. "Width of path of destruction from ten feet to 10,560 feet, "with an average of 1,369 feet."

e. "Length of tornado track (on ground (?)) from 300 yards "to 200 miles, with an average of 24.79 miles."

f. "Velocity of progression of tornado cloud, from seven to 100 "miles per hour, with an average of 44.11 miles per hour."

g. "Vortex wind velocities vary from 100 to 500 miles per "hour as deduced from actual measurement."

h. "The concomitants of a tornado are oppressive condition "of air; rapid decrease of temperature with increase of alti-"tude; a decided gradient of temperature across the line of

* Ferrel, page 325.

* See also Paper read before National Geographic Society, Washington, Nov. 16, 1888, reprint *Science*, Feb. 1, 1889.

"progressive movement; a characteristic funnel-shaped cloud "which on reaching the earth has four motions, whirling mo- "tion from right to left, progressive motion from SW to NE a "curvilinear motion and an oscillatory motion."

We come now to the second division of our paper, concerning the *possibility* and *practicability* of *predicting tornadoes.* We are not yet able to prevent the occurrence of tornadoes. The tornado cloud itself disappears, most probably, not when the conditions in the "whirl" no longer cause rapid condensation, but when, indeed, the conditions favorable to re-vaporization begin to strongly assert themselves. Could we copy nature, and provide those very oppositions, which she provides, we might, if not destroy, at least remove the tornadic action to regions where its effects would endanger neither life nor property. Coldness and dryness of the air are undoubtedly unfavorable to the growth of tornadic action, as per contra, warmth and moisture favor it. It is said, that tornadoes are unknown west of the 105th meridian, because of the dryness of the air. It may be pointed out here, too, that tornadic action originates not at the surface of the earth, but in the upper regions of the air. So also, in the disappearance of a tornado, it is in the upper regions that the tornadic action finally dies out. The lower part of the characteristic cloud is always the part which disappears first. But as we may not yet prevent, nor successfully interpose barriers between ourselves and the storm, let us turn our attention to the most profitable means of obtaining fore-warning of its occurrence. The Signal Office began on July 1st, 1886, the preparation of a special chart, having for its purpose, the indication of where a likelihood of tornado occurrence might be. This chart, after two years' trial, for reasons not made public, was discontinued, a general weather map being considered as serving equally well. State of weather, as regards cloudiness, wind direction, temperature and the depression of the dew-point below the temperature of the air, were entered on this map. *The regions of northerly and southerly* winds were distinguished from each other by heavy carbon lines. There is no criticism to be made upon this chart, so far as it goes; but it certainly suggests to an inquiring mind, an indefiniteness and incompleteness concerning those very features, on which the occurrence of tornadoes depend. In the Indications work of the Signal Office, for years, only the barest kind of attention has been given to the study of some of the most import-

ant of meteorological factors. The tendency to rapid generalization and hurry in the work of that Division bars, from careful consideration, matters of detail, it is true, but still of great importance in the making of predictions. The conditions are often so suggestive that it seems almost certain that their careful study could not fail to improve the percentage of verifications.

Unless valid reasons can be given, the tornado chart, or a chart that could be equally serviceable for thunder-storms, hail-storms, etc., should be reissued. And this chart should show, first, the border ground where currents from cold dry regions are brought into opposition with those from warmer latitudes. This was the design of the carbon line separating north and south winds, on the original map, as suggested, we believe, by Lieut. Finley. The second consideration, that of temperature, presents difficulty in charting, at the start, because we have not the means of ascertaining what are fairly representative temperatures, not alone of air strata but even of limited areas near the surface of the earth. We need in meteorology, above all things, *integrating* thermometers; some system of thermometry that shall sum up fairly, and represent justly, the heat effects over given areas. The new tornado chart should therefore indicate regions in which an unusual warning up of the lower strata seems to be in progress, particularly if this heating effect seems to be confined in extent to low air strata, while approximate higher strata seem to remain comparatively unwarmed. The use of the dew-point depression might perhaps be better served, by giving the absolute humidity of the air. As with thermometry, the value of integrating instruments is obvious, and the employment of isolated observations productive of but uncertain results. The features of wind direction and velocity as regards the proposed chart are most important. For, from the wind direction, and the direction of cloud movement (a matter singularly unappreciated by some professional meteorologists) we can obtain best, and independently of barometric indications, a knowledge of the gyratory motion of the atmosphere, relative to any centre; and the "fixing" or locating of this centre. The charts in the Indications Room of the Signal Office take passing notice of the directions of cloud movement, but no use is made of these directions as a means of locating centres of gyratory motion of the air. It is here suggested that this chart for use in tornado prediction show for all stations reporting, in addition

to the features above named, the velocity and direction of the surface winds *and also the directions and apparent velocities of cloud movement.* We can not over-emphasize the importance of taking recognition of the *upper*, as well as the lower strata of the air. In the actual charting the surface wind might be represented by an arrow, flying with the direction *below* the station, and the cloud direction by an arrow *above* the station. Where two or more kinds of clouds are reported, two or more arrows might fly above the station, the arrow representing the uppermost clouds having the uppermost position; thus

FIGURE 1.

cirrus clouds from west,
cir-cu. clouds from northwest,
stratus clouds from east,
surface wind from southeast.

Some scheme must be employed (as for example, prolonging the arrow HEADS of all *lower* directions, and the arrow TAILS of all *upper* directions, to the supposed (partially indicated) centre of gyratory motion) whereby these motions of air strata may be made to indicate, not alone the *general centre* of gyratory motion, but if sufficient observations are given, the TENDENCY to the formation of any *secondary* centre of gyratory motion.

The following diagram is offered in illustration of the suggestion (see chapter in Ferrel on "Relations between Upper and Lower Strata of Air"). Full arrows represent lower clouds, and dotted arrows upper.

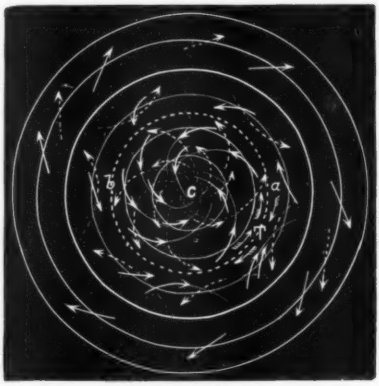


FIGURE 2.

We should strive in every way to obtain a knowledge that will enable us to locate definitely, not only the *general centres* of gyratory motion, but also the various *secondary centres* of whirl-

ing. We hear sometimes, of failures in prediction accounted for as "unaccountable." "Everything" we are told "seems to indicate that 'thus and so' would happen—and the predictions were made in accordance with known laws!" It is these very irregularities, these unaccountable (!) wind directions, these inexplicable (until subsequent explanations are attempted) delays in the progressive movements of "storm-centres," these unlooked for and unpredicted cold and warm "waves" that contain the very secrets of successful prediction. As it was from the perturbations of the planet Uranus that Adams argued the existence of the planet Neptune, and Leverrier directed the Berlin astronomers where to look to find it, so, we believe, it will be from a most careful and detailed study of these secondary whirlings in our atmosphere, that the seeming irregularities and uncertainties of the primary whirlings will be made known; and the prediction not alone of storms of marked intensity as *e. g.* tornadoes, thunder-storms, etc., be made possible; but the ordinary predictions of general weather conditions be made eminently successful.

DESCRIPTION OF THE TORNADO AT VIROQUA, VERNON COUNTY, STATE OF WISCONSIN, JUNE 28, 1865. A PRIZE ESSAY.

By John M. Bennett.

For the better understanding of this account a little of the geography of the country should first be given.

The city of Viroqua is situated on high rolling prairie, in latitude 43° 33′ N, and eighteen miles east of the Mississippi River. Its altitude is 800 feet above the river and about the same above Lake Michigan. No land in sight of Viroqua is much higher. The horizon appears nearly level with the city in all directions. The streams from the springs west of Viroqua have formed many deep channels, leaving numerous rocky bluffs, which, near the Mississippi river, are bare of timber; and their rocky sides and summits 500 or 600 feet high, present a romantic view. For this reason they named their postoffice Romance.

It was in this wilderness of intensely heated hills, and more than moistened valleys, that the tornado of that eventful day was generated and started on its fearful rush through the length

of Vernon county to its ending in Juneau county. Vernon county is forty-four miles long from west to east as shown by the original U. S. survey.

The weather conditions before the tornado are given carefully from my diary as follows:

June 26, 1865: Went to La Crosse U. S. Land Office, for the abstract of land entries for Vernon county. Weather fair and pleasant.

June 27: Abstract completed at 2 P. M. At 4 o'clock P. M. started for Viroqua. Fair weather. After driving out of the city found the wind blowing softly from the south. Stopped at Mr. Woodbridge's for the night. This place is on high land. At sunset a light breeze from the south.

June 28: At sunrise, dark low clouds passing briskly. Cooler. A stiff breeze from the south. Mr. W. says, "It will rain soon." Starting homeward before 7 o'clock, soon reached the valley below and found it warmer (the reverse of the usual condition at this season). On rising to another ridge at 8 o'clock A. M. felt the damp breeze again, but further on at 10 o'clock the clouds were dispersing, the sun shining and no rain yet. Heat increasing. Some cumulus clouds appear. At noon, sultry heat. More cumulus clouds appear. My horse sweating profusely, drove on the walk, and arrived at Viroqua at 1 o'clock P. M. The weather very warm but no showers in sight. No wind here. All is still till after 3 o'clock P. M.

The weather conditions so far are given as experienced in a drive over the country and ten hours' observation before the tornado. The reader will notice that my path was a dozen miles to the leeward of that wilderness of bluffs lying between the North and South Badax rivers, which had been heated by several days of sunshine, and whose atmosphere seemed more than supplied with moisture, as shown that morning at Mr. Woodbridge's. At an altitude of about 800 feet above the Mississippi we felt as if we were in the very rain clouds.

On this day about 3 o'clock P. M., local showers were gathering suddenly among these hills, around which rain fell in torrents. As one lady school-teacher expressed it, "the water seemed to fall in sheets," with sudden gusts of wind, so that while she was closing a window the water had fallen shoe deep on level ground in the street. Heat and moisture were there in disturbed equilibrium.

The scientist does not expect me to describe the force that can

produce such motion as was witnessed at Viroqua. The weather conditions are thus plainly described. I now take my standpoint on a garden elevation west of Main street, Viroqua, in full view of the western horizon to describe.

The Approach of the Tornado.—My daughter, passing from office work at about 3:45 P. M., said it looked so much like rain she preferred to be at home. This called our attention again to the clouds. Sharp lightning and sudden thunder showed a shower of rain some two or three miles away in the northwest. We could see also a shower in the distance southwest of us.

There appeared at this moment some miles directly west of us a dark, ragged cloud passing swiftly south, and another going north at the same time. On looking at one of them it *appeared* to stop and go the other way. We had never seen a tornado, but we now knew these clouds were moving swiftly in a circle. This warned us to seek for refuge, which we did as best we could, by hastening to the cellar of our house. But before leaving this position, a further view was taken, and here this whirling cloud should be further described. The top of the cloud as seen three miles away was only 7° or 8° above the horizon. The bottom was on the ground. The space occupied horizontally was some 15° or 18°.

The motion of this cloud was so rapid that the time of its revolution or rotation, was but two or three seconds, and its onward rush was nearly a mile in a minute. The further description will show the above to be nearly accurate.

Just west of Viroqua is a circular piece of land some fifty or sixty feet lower than the city, a half mile across, skirted with rocky hills sixty feet higher than the bottom of this scoop-shaped basin.

The top of this whirling cloud having so far been at low altitude, with this basin in its track, we can here well estimate its size. (The reader will keep in mind that this cloud was unlike any other; that it existed independent of rain clouds on each side; and that in its rush it outstripped all others. Although it rained at the time three miles north of us; no rain came with it to Viroqua. It will be shown that no rain accompanied its further progress of thirty miles).

Size of Cloud.—Before this cloud reached Viroqua it had been accompanied by a branch whirl, holding on like a parasite, which had not concentered with it. This caused a crooked or zigzag track in a part of the course, which was noticed by sev-

eral persons. All of this whirling mass of clouds, now gathered in this low basin, formed a dense cloud eighty rods in diameter horizontally, and about 200 feet deep from bottom to top. This is a good estimate of its size or quantity as it came to the outlet from the low ground.

It *seemed* that the cloud was blocked and retarded a little in its onward course by contact with the rocky hills near its outlet. In its gradually rising path, twenty rods wide, stood the large new warehouse of Herman Greve, with its store of produce and farm machinery and other things, including a large pile of fleece wool in bulk (not sacked). This building was strongly made. The lower stories were framed from oak timbers, hewed a foot square. Near this were his dwelling house and barn and sheds; near these a little further east, three other dwellings. The tornado cloud in its onward rush, climbing this inclined plane, came with such dreadful power that all these buildings were at once, or in a few seconds, taken up, with their basements even, and crushed and whirled together a few seconds and dashed upon the rocks around, causing a jarring of the ground many rods away, adding this terror to the roaring whirl. I think, by the distance these heavy timbers were carried north and south, some of them must have been raised fifty feet or more. No one could see an object a foot within the dense cloud.

At the time of this tornado but four of our family were at home,—myself and wife and daughter, and her little Emma Tourjee, six years old. When we saw from our west room the heavy timbers shooting from the cloud in all directions and the whirling mass coming on so swiftly, we went with all haste to the cellar with death in view, as we thought. My wife, the last to reach the bottom, just escaping the falling chimney, crept under a wide shelf about two feet from the ground in the SW corner of the cellar. As she did this, she uttered the prayer, "Lord save or we perish." We joined in the earnest supplication and from our hearts prayed for deliverance from the danger.

The house trembled two or three seconds and tipped over toward the north and was crushed in the whirl. Our shelter gone, timbers were immediately thrown upon us, and around us. My legs were caught among these broken timbers so I could not get away. Our house was soon emptied of its furniture for some of it, crushed, was near the bottom of the large pile, of which three of us formed a part. Our position was a terrible one. My daughter was seated on the end of the shelf under

which her mother had taken refuge, with her little one clinging to her for life. All was now in a darkness, which we could feel. Not a hat or cap, hair-net or hair-pin left. The hair of our heads in a whirl, we were for one dreadful minute pierced with flying splinters, our eyes and hair filled with mingled street dust and pulverized plastering, mixed with blood flowing from our bleeding scalps. The severe bruising we received from flying debris was continuous; often, in fiercer gusts, it seemed that we were in the vortex of a whirlpool of thickened darkness. Now a heavier crash came, we knew not what. Timbers were still making the pile upon us of larger size. We could not see at all, but could feel the jarring and pressure of additional weight.

While we speak of this as a thick darkness, and a darkness which we felt, we do not attempt to compare it to the miraculous darkness once in Egypt; but we speak of the state of the fluid (?) or the substance (?) in which we were densely enveloped. It was here a little sticky. It was difficult to breathe. It permeated all the space within its circle. It rushed upon the ground twenty miles, and then another twenty miles of aerial passage without evaporation or loss of any of itself. It did not mingle with air currents on the way. It was a thing of itself, existing while its swiftly whirling motion lasted. Will the scientist tell us something of it?

A few words more of the cellar experience. While, amid this dreadful roar and gloom of the darkness, we waited for sudden death or for the passage of this wondrous whirl, soon, and as suddenly as it came, the whirling motion ceased. We were at once in a calm. The darkness fled away. I could move my head and one hand. I wiped the bloody mortar from one eye and beheld the desolation which was there.

When the tornado reached us my horse was in his stall, fifty feet east of our cellar. During the darkness he dropped from the whirl directly upon us. His head was by the side of mine so I could breathe in his face. He was held here in his struggles by timbers around him. My legs pained me and on looking down to see their position, I saw the horse's forefeet upon the key board of that organ which a few minutes before was so valuable to us on account of its memories. Choice keepsakes of years were ruined or gone, now. Our situation was perilous and gloomy, and our chances of escape lessened by the struggles of this live horse.

Joy came to my heart, and I felt greatly encouraged when I

saw my wife come unhurt from her hiding place, to call us to know our condition. Our daughter was able to get out of this dangerous place; and the two women, somehow, with great energy rescued the little one from danger, while I kept the horse as quiet as possible, by rubbing his face, calling his name, and breathing on his nose. I then told my wife that they could not get me out and urged them to keep away from further danger till help might come.

At this point I fainted. (I had been severely bruised, and crushed almost to death, from the falling timbers to which was added suddenly the weight of the horse. My right leg was broken near the ankle and the joint so badly injured that I had to use crutches for ten months). While in this unconscious state two strong men came along and drew me out, it was said, and laid me on the ground to die, away from the struggling horse. When consciousness returned, I told my wife I was cold and wished for some cover. This was not easily found.

Now, instead of the roar of crashing and whirling of timbers, was heard the groans of the dying, the shrieks of the frantic, and the voice of friend calling for friend. One frantic mother calling for her babe, gone in its cradle. In the house next west of us were two adult persons, both of whom were killed. In the house next east of us were four aged persons all of whom were killed, or soon died of injuries received.

The street running east from us was then the south street of the village; this was the straight track of the tornado. On this street ten persons were killed or received fatal injuries, which was one-half of the residents at the time. Every building on each side of the street was destroyed.

These descriptions of our experience have been given in part as illustrations of the power and the velocity of motion of the tornado as felt and seen. Marvelous circumstances attending this event might be told, and facts of interest related as further illustrations, but words in this essay are limited, and as the further track of the tornado is to be followed, these incidents cannot be related for want of room. We now describe

The Further Track of the Tornado.—The straight track of the funnel-shaped cloud was fifteen or twenty rods wide generally,—less on lower ground, wider on high ground.

Here should be stated the facts concerning the wider track in Viroqua. This cloud as it crossed Main street was whirling on its track, widened to seventy or eighty rods from south to north,

which lasted but a minute or two. I have before related the fact that the lower portions of the cloud *seemed* blocked by the rocks skirting the basin west of Main street. Now, the upper and wider portions overflowed the barriers and in this disturbed condition took the form of branches of the main portion, and here and there reached down and destroyed any building in their way.

The lady observer who courageously watched this movement of the cloud from her standpoint outside, said these "eddies" or branches appeared to whirl with the same velocity as did the main column. Several buildings and dwellings, the church building, the store of Nichols Brothers, the court house roof, the printing office, and a few other buildings here and there were destroyed, while the cloud was in this divided and widened form, but the motion was so rapid that immediately these branches were converging and all at once concentrated in the main column, now rising higher and moving off in sublime splendor.

The dark column which had hugged the ground so closely, now in the form of an inverted cone, rising in strength and power, its point still on the ground, bore aloft as trophies of the conquest many keepsakes and precious endearments of homes so quiet and happy before. It had also the shingles of sixty buildings, large and small, and much clothing from destroyed homes, and that large pile of wool which singularly marked its aerial course for the distance of thirty miles!

The Onward Course.—One or two miles east of Viroqua in the track of the tornado stood a school-house containing the teacher and twenty-four pupils. At a speed of nearly a mile a minute the whirling column came to this defenceless group, on the open prairie, who without a minute of warning were taken up with the house and dashed to the ground with timbers falling upon them, and thus every fourth child was almost instantly in the embrace of death.

The teacher, Miss Annette S. Phillips, a young woman from Vermont, received injuries from which she did not recover. I give her name because of her fidelity and kind care, and true courage and coolness in such a trial.

Mr. C. Brown went across a field to this sad scene. He was the first one to reach the place after the tornado passed, and found Miss Phillips had taken the best care she could of the dying children. Five of them were already dead and she was sitting on the ground holding on her lap the sixth, a beau-

tiful little girl, whom she was caressing and soothing in her dying agony.

From this time on, no other persons were injured. Two or three dwellings were destroyed, the inmates escaping. Several of the inhabitants lost some acres of good timber thrown down entirely. At the West Kickapoo river were timbered hills and bluffs 400 or 500 feet high, which blocked the cloud, and here, rising in power above the hills, its course changed to northeast, which course it kept above the timber till it reached the East Kickapoo river near Mr. Fulmer's, below Rockton, a distance of ten miles.

Mr. D. M. Fulmer, now of Oil City, Monroe county, who was for several years a successful school-teacher of Vernon county, and should be trusted for correct mathematical estimates, gave me the following description of the tornado as he saw it in its aerial passage:

Aerial Passage.—Mr. Fulmer said he was plowing among corn in an elevated field in the Kickapoo Valley. While looking toward the southwest, he saw the tornado cloud rising to view above a distant hill. It approached swiftly. It was balloon-shaped. It was at an altitude above the highest hills. It appeared a dark dense cloud forty rods or more in diameter.

He could not describe the grandeur as it came nearer in its passage. The roaring sound as of a waterfall, its rapid rotation, its onward rush of about a mile a minute, all combined to render the view most impressive, the wonderful sight of a lifetime, which he enjoyed four or five minutes, while the cloud was passing as many miles.

There was no wind or storm at the time. The weather was fair and warm. All was still except the roar of the tornado cloud.

The course of the river valley below Rockton is southwest. The aerial passage here was northeast and central over the valley. The shingles, wool and other things from Viroqua, which marked the track, fell in a path a half mile wide, showing the cloud to be more elevated as it progressed.

Mr. Fulmer was particular in giving me this account relating to the altitude of the cloud, and said that, as it came in sight and as it passed out of sight, it was entirely above the highest hills. The time of the appearance of the cloud at Rockton was 4 o'clock or but little later.

When the cloud passed the valley near Rockton, the course

changed from NE to NE by E, this change of course being known only by the material dropped. Two miles further on this course was found a cloak uninjured belonging to a Viroqua lady. Ten miles further on, the cloud passed the high timbered lands of Forest. It was at a higher altitude over the valley of the Baraboo river, and was here expanding as shown by its marked track, widened here at the center of Hillsborough township to three miles. The speed of its onward journey abated as it expanded and its power to hold and convey its marking material was lessened, so that these substances dropped in greater abundance after being thus conveyed more than thirty miles.

The family of William Mutch, my son-in-law, resides on section one of Hillsborough township, near the line between Vernon and Juneau counties. I give in their own words the description of the

Tornado Near its End.—Mr. Mutch says he was plowing in his west field between 4 and 5 o'clock P. M. when it suddenly became cloudy and grew dark and gloomy. He thought it might soon rain and started on a fast walk behind his horses for the barn. After walking some forty rods he saw shingles dropping from the cloud over his head which drew his attention to it in surprise. He now saw the rotary motion which he had not before noticed. The fact that the clouds were dropping pieces of paper and cloth and locks of wool was plain, but how it could be was the wonder! On reaching his house he found the little ones had been picking up shingles which they said dropped from the clouds. Mrs. Mutch had found in the yard the diary of one of Viroqua's physicians, and also a letter which had been kept by one of our Viroqua neighbors whom she knew.

It should be stated that the expansion (not evaporation) of this wondrous cloud continued. At Juneau county line its marked track was six miles wide. It had not the power to convey further the material carried so far. The lighter papers and shreds were seen on almost every rod of ground. Years ago I was on my farm at Hillsborough and decided to ascertain if possible further facts in relation to its height and expansion. I asked Mr. Mutch how high it was. He could not tell. From his statement that when the cloud came over him he hastened to reach the barn and walked forty rods before the material fell around him we may estimate in this way. (If you will allow

me to use the falling wool in getting this approximate height it will be as convenient as a self-registering thermometer in a cold night. There was no one to take the altitude). While he was walking forty rods the shreds of paper and cloth and locks of wool, at a little greater speed, had fallen sixty rods from the cloud above him or about 1000 feet. Mr. Mutch's farm is some 400 feet higher than Elroy. The cloud if ascending in the same grade would reach the height of 1,500 or 1,600 feet at Elroy. The country east of Elroy was then a wilderness. No observation of the cloud was taken in its further progress.

I omitted in the proper place to state that the cloud was whirling from south to north on its approaching side.

The prevailing weather conditions have been carefully given. The local showers among the hills were indeed terrific, the water pouring down with heavy gusts of wind. This was just before the tornado reached Viroqua. None of these showers accompanied the tornado on its way. That cloud, as I have stated, was a different thing, speeding away most hurriedly from the region of showers. It contained no rain and no rain was with it east of Viroqua. Two or three hours after its passage it rained at Viroqua powerfully for a half hour, after which the weather was fine as usual.

I have given the facts in this essay with much care and have written it with great effort because of feeble health, as I am now in my eightieth year.

I am under obligations to several intelligent persons living near the tornado track for particulars and facts and would like to give their names had I room.

If this essay is not already too long allow me to state some further facts to show the rapidity and power of the inner motion of that wondrous whirl. In the chamber of our adjoining wood-house, some fifteen feet east of us, was placed in summer storage our light sleigh. I said the house trembled two or three seconds on its foundation before it was crushed; I now write what we could not see or hear. During this short time of trembling the wood-house was unroofed, the sleigh taken out and carried the fifteen or twenty feet west, and placed on the north side of the house to be crushed into the ground by the north wall as it fell, (so found days afterwards). I said the flying of debris was continuous—often in fiercer gusts. Within the next minute a fiercer wave of power had reached our 1100 pound horse and carried him fifty feet west, or backward in the whirl

and dropped him feet downward upon us among the timbers so he could not get away. I relate one more marvelous fact which comes in this connection and which may give rise to valuable thoughts in some future discussions of these subjects.

Mr. H. Allen, superintendent of schools, was in the Viroqua school-rooms at the time. His horse, but little heavier than mine, was in a stall only four or five feet from him on the south side and was tied to a small stake driven for another purpose into the ground floor of the stall. It was a slim fastening and had no connection with the building, in the east end of which were both horses facing the east. When the tornado had passed, this horse was still there tied with his light strap, without harm, had not even the scratch of a splinter to be seen upon him, and apparently he had remained unmoved still facing east. All the building was swept away except the sills, and no windbreak so high as his knees was near. These circling waves of power had missed this horse which was the only animal or thing above ground left unmoved in all the straight path at Viroqua.

A man living a few miles south of Viroqua, who was in town with a heavy pair of horses and new harness and heavy wagon, seeing the tornado approaching, thought to escape by driving out in haste. Main street running south has a down grade. He had his team on the run, but the whirling cloud was on the street before him, and while our cellar was covered with the cloud he rushed his team into the whirl, just in time to be the last transport to the cellar. The man and boy and wagon box were unloaded by one of the branch whirls or "eddies" a little further north. The wagon wheels and axles, with reach broken and wheels "telescoped," were some ten feet from us in the NE part of the cellar, the horses both on their backs between the wheels. Nothing was over them so we concluded they were the last to come in. Now this cellar was about full except the SW corner, which Mrs. Bennett was occupying. This corner, as described in the essay, was the safest place.

In this essay I have described the tornado cloud in its disturbed form at Viroqua. The perpendicular rocks, which for a moment were its barriers, caused its widened form and slower progress, so that it was more than a minute passing a distance of forty rods onward in its destructive course.

I repeat the fact of its separate existence and, whether science shall call it fluid or vapor or other name, the substance was here in great power and motion without connection with other

clouds or air currents, but every fragment of it was whirling and all combined in the great destruction and finally and suddenly all concentered in one sublime whirling column leaving none of itself behind except some of its sticky or adhesive quality upon substances of contact. I will relate a fact to show further the wonderful combination.

Our youngest daughter, then at school, had arranged some ornamental articles upon a table in our west room. There was one mat, nearly a half yard square, of fine wool cloth wrought with skillful needle work in brilliant colors; on this was spread a smaller one, on these a little bottle of perfumery. While our house was being emptied of its contents, a portion of the cloud took mat number two up Main street north thirty rods and dropped it so that it was drawn into a store with the air current as they were closing the door. But the main whirl took mat number one and kept it nearly an hour and then dropped it in a fence corner on section one in the township of Hillsborough. A few days later Mrs. Mutch, who made this mat twelve years before at Springfield, Vt., had it again in her possession thirty-two miles from us. Our younger daughter also had hers, carried by the same power some thirty rods.

In the same room we had some good books; among those more valuable was a large Bible, bright and sound, containing some 1400 pages. During the short time of the passage of the cloud, 700 leaves of this book were moistened and each page sprinkled with mingled road dust and pulverized plastering. This dredging was more profuse on some pages, but all had the sprinkling. Several other books were also thus dredged. The books were carried to a shelter before the rain that evening. I did not see them until some days after. Then this dust was stuck fast and could not be removed with a brush or wiped off with a cloth. To remove the dust thus adhering so firmly, we used a thin, straight-edged table knife and whittled or shaved it off, and then with a soft brush cleaned each page. The book had not the stain of water and those pages are now bright and clean. Now the marvel is how were 1400 pages thus turned and sprinkled in so short a time, less than two minutes, and not a leaf torn or wrinkled. No mark of injury was upon it but dust. Some of the other books showed the rapid dredging, but they were more or less otherwise injured. The above is related to show the fact of great rapidity of motion and the slightly glutinous quality of the cloud.

Means of Protection from Personal Harm.—Nearly all tornadoes in the United States approach from the west or southwest, and may be heard or seen in time to reach a place of refuge if such place is prepared.

Every dwelling-house should have a dry cellar. The living room should be in the southwest corner of the house. Across the southwest corner of the cellar an arch or scaffold should be built some three or four feet from the bottom. If built of timber let it be charred or oiled with coal oil to prevent decay. The space beneath this arch or scaffold should always be empty in summer. Its hasty occupancy might be greatly needed some hot afternoon. All should learn to be observing.

The best tornado insurance would be a continued subscription to the AMERICAN METEOROLOGICAL JOURNAL, or some periodical devoted to the interest of science, from its pages to get interested in some higher knowledge. Then sudden weather changes would be noticed; and during prevailing unusual weather conditions some one of the family would be likely to notice danger, if approaching.

The dreadful sound of such a tornado as Viroqua witnessed could be heard for two minutes before its near approach, in that time all could get shelter in the cellar arch.

The thoughts concerning the safest part of the cellar are from our own experience. As I have already related, my wife had her place in the southwest corner of the cellar, and was not hurt, while the others of our number were buried in the ruins, and barely escaped with life.

Persons who keep a diary of events and weather conditions and write a little every day in the year, learn consequently to be observing.

Better obtain the knowledge which the scientist is publishing for you, than pay for other tornado insurance.

Since 1865 I have known more of tornadoes than before, and if overtaken again, as then, would get to the southwest corner of the cellar if possible.

TORNADOES. A PRIZE ESSAY.

BY PROFESSOR H. A. HAZEN.

Definition.—A tornado is a destructive, electric storm, of great suddenness, very limited in extent, and often attended by deafening roar and a funnel-shaped cloud.

It seems rather surprising that it should be necessary to specify destruction as the most essential characteristic. It is easy to see, however, that a funnel-shaped cloud which does not reach the earth can be regarded only as a seeming tornado. It certainly is of no interest either to the public or science, and yet, by some, such a cloud is counted as a full-fledged tornado. We certainly have no means of studying a tornado except by its effects, and these must have the most prominent place in the definition.

It will be understood that, while the most violent tornadoes have all or nearly all these characteristics, yet there are many graduations in their violence, but it is essential that every tornado be sudden, limited, and be felt of some violence.

Authorities.—In making a study of tornadoes we shall confine ourselves to those which occurred between the years 1873 and 1888, in the states east of Dakota, Nebraska, Kansas, Arkansas and Louisiana. The most complete record of these at our disposal is in the *Monthly Weather Review* of the U. S. Signal Service, which contains a record of most of the destructive storms of this period. There are also published papers by Mr. Finley, and in addition occasional descriptions of storms and discussions of the same in the journals and newspapers.

Scale.—The establishment of a scale of violence is one of the most important steps to be taken in a practical study of this question. The utmost confusicn has arisen from calling every funnel-shaped cloud a tornado without regard to its effects. It is manifestly a most difficult undertaking, but it is hoped at this time to make at least a beginning toward a scale, which, however, may need slight modification in the future. It would seem as if a tornado, by its very definition of very limited extent and destructive, ought to be located without difficulty, but this is not the case, except with the most violent, which, unfortunately, are located only too well. So difficult is the problem that some have abandoned all mention of towns and give only the name of the county or counties through which the tornado

passed, but this is very unfortunate and at once lands us in a region of uncertainty and indefiniteness, which must make all discussion exceedingly vague. It is a little singular that the very persons who resort to this county scheme always pick out definite photographs of the destruction in the very worst tornadoes, for illustration. We are very liable to obtain an entirely erroneous idea of the average tornado unless we can set by themselves the worst, the weakest, and those between. A scale of three has been adopted, and after great pains every tornado that can come under any one of these has been catalogued, making a total of 2,221 tornadoes, or 48 (3), 988 (2) and 1185 (1). The whole list is too long for this paper, but the 48 of scale (3) may be found near the close of this paper, and will enable one to see the character of the severest of these storms. A slight attempt has been made to exhibit a gradation in these, for example (3+) indicates the most severe and (3—) the least severe in class (3). It will be distinctly understood that the object of the scale is to exhibit violence and not necessarily destruction.

Destruction.—While violence is manifested by effects upon trees, water, sand, in carrying heavy objects, etc., yet destruction must be reckoned by actual loss of property, and here we are beset by most serious difficulties. While it is believed that the destruction by fire is known within about four per cent, and this covers the whole country, and amounts to more than twenty times that by tornadoes, yet it is probable that not more than one-half the destruction by tornadoes is reported, and it becomes necessary to estimate it. The cause for this has been the lack of persons sufficiently interested to make a careful canvass and the inherent difficulty in the work, and, as a result, the wildest estimates have been made by those who unfortunately desired to make the loss as great as possible. One example will suffice. A printed table gives the total number of tornadoes in this country, from the earliest times to 1887, as 2,435 and the loss by these as $941,282,500 or $386,564 for each tornado. In the list of the 48 most severe tornadoes the average destruction is about $186,000, so that by the above estimate this country has had 2,435 tornadoes, each of which has been twice as destructive as the average of 48 of those known to be most destructive. The average destruction of the 2,221 tornadoes between 1873–1888 is $17,645 and this is believed to be a *large* estimate for each tornado. Further comment is unnecessary.

In studying this subject we find two natural divisions, "Facts"

and "Theories" and each of these may be divided into "General" and "Specific."

FACTS.

(*General*).—*Electricity.*—Perhaps the most important fact of all is the intimate relation of electricity to a tornado. Indeed it has been well said that a tornado is the extreme development of a thunder-storm. Till quite recently this relationship was almost universally admitted. See Blodgett "Climatology" pp. 376 and 402; Brocklesby "Meteorology" p. 64. A study of the environment of tornadoes will reveal a general existence of numerous thunder-storms, and it is admitted by all that hail (which is essentially an electric phenomenon) is a constant attendant upon tornadoes. A good proof of the coexistence of these phenomena is to be found in the *Monthly Weather Review* for August, 1886, where there are two weather maps giving the general conditions for the dates of severest tornado and thunder-storm action during the month, and these two, drawn entirely independent of each other, are for August 16. While lightning is not observed very often in the funnel yet a glow has been noted there, and frequent vivid flashes and intense thunder have been noted very near the funnel.

Southeast of a General Storm.—If we examine weather maps for tornado dates we shall almost invariably find the severe storms in the southeast quadrant of a general storm and about 400 miles from the centre.

Hour.—Tornadoes usually begin at 3 or 4 P. M., or at the hottest part of the day. A most significant fact is that usually there are several tornadoes on the date, all having parallel paths and moving to the northeast. The general motion of these paths, however, is toward the east, where the air is continually growing cooler. These tornadoes may take a start as late as 8 or 9 P. M. and the later paths are always three or four hundred miles to the eastward of the first.

Velocity of Tornadoes.—We may determine the velocity of the general storm from day to day with much certainty, but the velocity of a tornado is much more difficult to learn. We know, however, that this is much greater than that of the storm, and generally nearly double the latter. The same fact has been learned of thunder-storms. This is very important and seems to show that the progressive motion of the tornado is independent of the upper current in which the general storm is moving.

Winds and Currents from South.—Another important fact brought out by these maps is that in the tornado region the currents are all from the southwest, south, or southeast, even up to great heights as shown by the clouds. This fact could also have been learned from the general circulation of the atmosphere about any extended storm.

Temperature.—The heat of this region is much above the normal and is described as especially enervating and entirely different from the ordinary heat of the sun. This heat is even more debilitating with a clouded sky than under ordinary circumstances with a full sun in a clear sky.

(*Special.*) *Meeting of Clouds from NW and SW.*—The almost universal testimony of eye-witnesses of tornadoes is that they appear as two low-lying clouds, dark and threatening, the one in the northwest and the other in the southwest. As they approach they seem to coalesce and form the tornado. It is admitted by all that two clouds of specific velocity cannot produce on meeting any motion greater than that of either. These clouds being on a level, or nearly so, cannot produce an unstable equilibrium by contrasts of temperature, as thought by some, which contrast must be in a vertical and not horizontal direction. If there be mingling of these clouds, it can produce no marked effect whatever, through heat or velocity, but it does not seem incredible that through the intervention of electricity the most violent and destructive results may follow.

It would seem, however, as though this mingling to form the tornado is an optical illusion. Probably the same appearance of two clouds from NW and SW would present itself to a witness anywhere along the path of the storm (I mean for miles along the track) and this could hardly be the case if there were a union at any point. The tornado is undoubtedly in existence between the two clouds, but cannot be seen at first because of a cloud of dust or haze in front. This dust-cloud has been observed again and again in front of a thunder-storm, and, in fact, is a precursor of all sudden or rapidly moving storms. The two clouds on either side, may seem at a distance, because one is looking through quite a mass, but when they approach the observer, the space between and the tornado are seen more plainly, while the clouds on either side gradually disappear, because one looks at them then through a thin veil, or side wise instead of "end on."

That these seeming clouds attend the tornado and do not unite is proved by the fact that there is a continuous devastation by

the side of the principal track. The most serious destruction, outside of the immediate tornado track, is found on the south side and this has generally been ascribed to so-called SW indrafts because the debris almost all point toward the northeast. This destruction was very plain indeed at Wallingford, Connecticut. It is highly improbable that this could have been caused by wind blowing toward a partial vacuum because the debris did not present the direction or distribution they would have done if such had been the case. The destruction was only here and there in strips and not at all complete as would have been the case with a uniform rush of wind. It had the decided appearance of being due to the same force as that of the tornado itself. One thing is absolutely certain and that is that there was no evidence whatever that a cloud came from the southwest; this was most carefully looked for, to the southwest of the town, in the direction pointed out by the witnesses, and there was nothing to be seen outside of the tornado track, which was nearly due west, and its immediate environment. This explanation of the two clouds is very important, because many have maintained that the whole force of the tornado is due to the warring of the cold northwest cloud with the warmer southwest, and the enormous contrasts of temperature, when the clouds have united, have produced the tornado. At Wallingford these so-called southwest indrafts passed over a cemetery and knocked off here and there a monument. It was computed from careful measurements that this would have required a wind of at least two hundred and sixty miles per hour or an equivalent force.

Air Pressure Rises Within.—We had several observations of a rise of pressure in a tornado but none of a great fall. A great number of barograph registers have shown a rising pressure in a thunder-storm and it is generally admitted that in such storms this is the case. An excellent illustration of this effect may be found in Sprung's "Lehrbuch der Meteorologie," p. 291, Fig. 67, and in "Weather" by Abercromby, pp. 237 and 247.

If the tornado may be evolved from a thunder-storm this rise of pressure would be proved. Some think that the air rushes in from all sides and there must be a great diminution of pressure to enable it to rush up in the center. The uprush, however, is very problematical, and if we regard the tornado as passing with great speed onward with a whirling motion, the air need not rush to the center, but would be more and more tangential as the center was approached.

Wind Sudden, and From Tornado.—We find the wind just before the tornado generally from the south and gentle, but the storm breaks in from the west with a most violent wind, without any first high wind from the east, as would be expected if there were a partial vacuum into which the current first flowed.

All Debris in Center of Track Parallel.—One of the most significant facts, but one which has had little attention given to it, is the distribution of the debris. At the center of the track all timbers, boards, etc., point in the direction of the path. There is no appearance as if these had been sucked up and then thrown outward, but the whole aspect of the destruction is as though a downward thrust had been exercised. The appearance is very much as though a mighty and swift-flowing current had flowed over the ground and left all timbers parallel. It is believed impossible to account for this phenomenon by the view that these timbers were forced inward into a partial vacuum, carried upward and then distributed; that certainly would destroy the extraordinary parallelism noted.

Fowls Stripped of Feathers.—A peculiar phenomenon, and one not easily accounted for, is the stripping of feathers from fowls and clothes from people. It was thought at one time that the partial vacuum caused the air in the quills to suddenly expand and thus throw them off, but this view is now abandoned. Others think that the mighty blast blows off the feathers, but it is certain that long before any wind could even begin stripping off the feathers it would carry the whole fowl along, feathers and all. There seems very little doubt but that we have to deal with an effect similar to that produced on the hair by receiving a charge of electricity, while the person is insulated. In the case of the fowls the electrical charge is so intense that the feathers are thrown off. We have well authenticated cases of persons being stripped of their clothes by lightning strokes, and this seems an analogous phenomenon.

Effects upon Substantial and Frail Structures.—That the destruction is not produced by a violent rush of air into a partial vacuum, or wind whirling about a center, is abundantly proved in numberless instances, in which two structures, side by side, the one frail and the other substantial, have been affected very differently. Repeatedly, the latter is completely destroyed and the former in no wise scratched or injured. We have a report of two barrels, close to each other, the one full of

ashes and the other empty; the first was completely obliterated, while the other was left unharmed. Here again we may invoke the aid of electricity, which, by discharging under the one structure, would affect only the immediate environment, while a powerful rush of wind would sweep all before it, and, in any case, the frail long before the solid structure.

Apparent Bursting of a House.—A remarkable phenomenon is the throwing out of the four sides of a house. It does not seem necessary, however, to invoke the aid of the air expanding enormously on the release of pressure at the passage of the tornado. One of the houses in the Wallingford, Ct., tornado of August 9, 1878, presented this appearance, except that the east, north and west sides were thrown outward, while the south side was thrown into the center of the ground floor and the roof partially fell upon it. It was very much as though the tornado had driven in the south side and the compression on the interior had thrown out the other sides. But this may be accounted for in another way. Professor Joseph Henry held the view that thunder was produced by the violent rupture of the air particles on the passage of electricity. Now, if electricity should pass with great violence into a house it would have a tendency to explode it from the increased pressure inside. That the sudden passage of electricity will increase the air pressure has been proved by laboratory experiments. In a house near Washington, D. C., that was struck by lightning in August, 1885, the stroke passed between the weather boarding on the outside and the lath and plaster on the inside; both were violently driven apart, as though by an explosion, over a surface from top to bottom of the house, and five or six feet wide.

Dipping and Rising of the Tornado.—There is a peculiar up and down motion in the tornado which has been described by hundreds of witnesses and seems to prove that most if not all the destruction is begun by a downward action. This motion is entirely independent of the topography, and, indeed, it has been well proven that the topography of the country has nothing to do with tornado action. The dipping is so well manifested, that, right in the center of the track, there are left spaces without destruction for several rods, beyond which the destruction again begins.

The Deafening Roar.—The roar accompanying many tornadoes is almost indescribable. It has been compared to the passage of a thousand trains of cars. The same roar has been

distinctly heard in a very violent thunder-storm. It is a somewhat confused and prolonged thunder produced by a more or less continuous action of electricity which gives the sound a most peculiar effect. There can be no doubt that it is caused by the passage of electricity.

Distribution of Debris.—Aside from the immediate destruction, in which the timbers, etc., are found lying parallel to each other, great quantities of debris are carried forward and deposited at intervals on either side of the track, and for miles from the point of principal devastation. This, undoubtedly, is the main argument in favor of an uprush of air in a tornado cloud, but by no means proves it. It is plain that the debris does not rush into the vacuum because nature abhors it, but it must be carried by the air current. In front of violent thunder-storms dust and leaves are carried forward at the height of several hundred feet, and in this case there certainly is no uprush.

The same effect may be produced on much heavier articles in a stronger wind.

Rainfall.—It is an interesting fact that rain invariably falls in torrents immediately after the passage of the tornado. If this were formed in the uprushing current, as believed by some, and this uprushing current carried debris, etc., forward before depositing it, it is plain that the rain would also be carried forward. In fact this is the very explanation advanced by some, in trying to account for the occurrence of most of our rainfall 300 or more miles in front of a general storm center. It is said that while the rain drop is formed in the uprushing current at the center, yet, because of the greater rapidity of the upper current, it is borne aloft for hundreds of miles before it falls. Since almost a deluge of rain falls to the rear of the tornado and none in front, we must conclude that the uprushing current is problematic at least, and that rain is not caused by condensation in such a current.

Condensation.—Experiments have shown that a vertical velocity, in the uprushing air currents, of 100 miles and more per hour would not be sufficient to produce expansion and cooling at such a rate as to begin, even, the process of condensation. In some recent experiments a receiver, containing air at about 95 per cent. relative humidity, was connected with an air pump and the air suddenly exhausted to the extent of two inches, equivalent to an uptake of about 2000 feet; no fog was pro-

duced in the receiver, and there was an actual diminution of the relative humidity. These experiments have been repeated again and again with great care and all of them go to show that the ordinary views of condensation, due to expansion in an uprushing current, are very much at fault, and entirely erroneous. The cause of this rain, or indeed of any rain, is exceedingly doubtful, but the opinion is steadily gaining ground that it is an electrical effect. This is the view of R. H. Scott in his "Elementary Meteorology," and of Abercromby in "Weather." Experiments in England have shown that it is a comparatively easy matter to precipitate dense fog as globules of rain by the aid of electricity. After a flash of lightning, overhead, there has been repeatedly noted a great downpour of rain, showing distinctly a cause and effect.

Uprush of Air.—I regard this matter as perhaps the most important in all this discussion. The most widely and tenaciously held view of tornado generation is that it is caused by a most violent uprush of hot moist air which, by the cooling of expansion, condenses its moisture, and this liberates latent heat or caloric, which increases the vacuum, and that in turn increases the uprush, etc. It seems very plain that, since the liberation of latent heat would simply reëvaporate the moisture, no rainfall can ever be produced as long as any latent heat becomes sensible. In order that any cooling at all may take place in an uprushing current, it is necessary that the heat be taken up by surroundings, and, if this be so, the air previously saturated now has a greater capacity for moisture and is unsaturated. The effect of the passage of a mass of air into the cooler strata above would be virtually the same as mingling two masses of air of different temperature, and it is now universally admitted that such mingling would produce no rain or marked effect.

THEORIES.

Planets and Tornadoes.—There are a few not uneducated people who place great faith in the occurrence of tornadoes upon certain aspects or positions of the planets respecting the earth and the sun. It is a little singular that these people, I believe without exception, regard the happening of earthquakes, cold waves, hot waves, blizzards, pestilences, frosts, ice formation, etc., in the same light as tornadoes, and draw their confirmations from the occurrence of any of these in any part of the world. That the passing of a planet through its

equinoctial points, or that its coming in the same vertical plane as the earth and the sun, can possibly affect terrestrial weather, or in fact anything in the universe, is too absurd to demand more than a passing mention.

Sunspots.—The question of sunspots, however, is entirely different and it may be well to examine it briefly. Nearly all attempts to connect sunspots with the weather have signally failed. See "The Sun," by Prof. C. A. Young, pages 153–166. It is known that there is a marked connection between sunspots and terrestrial magnetism. See "Encyclopædia Britannica," article on "Meteorology." It is probable that they are caused through some cosmical influence and are largely electrical in their formation; if this be the case why may they not indicate a change in solar activity, and, if so, a corresponding change at the earth. Terrestrial meteorology is dependent upon the combined action of such a large number of influences that it is almost impossible to separate out the effect we wish to study.

Sunspots and Temperature.—Take the single case of temperature. If sunspots indicate increased heat in the sun, that in turn will produce greater evaporation on the earth and more clouds, which will ward off the sun's heat during the day time, but at night they will tend to still more complicate the problem, by preventing radiation and retaining the heat. More clouds, in general, mean more rain and probably a tendency to an increase in storms both in violence and duration, etc. It would seem no proof of a lack of influence, because all attempts at a direct comparison between temperature and sunspots have resulted negatively.

Thunder-storms.—One great difficulty in comparing thunder-storms with the appearance of sunspots has been the lack of reliable records of the former. The Smithsonian Institution made meteorological observations in this country between 1849 and 1870 and the Signal Service since the latter date. Till very recently these have consisted merely in the mention of the fact of the storm without regard to its intensity. A study of these records has shown a distinct increase of thunder-storms with the increase of sunspots, though a comparison in Europe has given an opposite result.

Cyclones.—Meldrum has shown a rather marked increase of cyclones in the Indian Ocean with increasing sunspots, and it has been partially established that famines in India occur with

a diminution in solar spottedness through a diminution in storms and consequent falling off in the rain.

On completing the scaled list of tornadoes in this country the total for each year was tabulated, giving each class its proper weight, with the following result:

Year.	Tornadoes.	Sunspots.	Year.	Tornadoes.	Sunspots.
'73	8	701	'81	169	730
'74	15	601	'82	286	1002
'75	69	272	'83	589	1155
'76	68	122	'84	462	1079
'77	111	92	'85	374	811
'78	108	24	'86	243	527
'79	92	49	'87	183	
'80	269	416	'88	259	

The sunspots are taken from Greenwich photographs, the figures indicating the average daily spottedness in millionths of the sun's surface. Owing to the scarcity of observations in the earlier years of the tornado record we cannot give them much weight during that period, but, since 1877, there has been a most remarkable coincidence between these phenomena, and the more singular as it was entirely unexpected.

It has been generally reported that 1884 was the year of maximum tornadoes, and certainly there seemed to be a greater number in that year, but the scale of violence gave the greater intensity to 1883, which is also exactly the year of maximum spots. It will probably be conceded that the present year, so far, has a much less intensity of tornadoes than last, and it is also the minimum year of spots. It will require more than a single cycle of spots to establish this relation beyond question, but the evidence strongly supports the view, that tornadoes, as well as thunder-storms, have a large increase during a period of maximum spots. This might have been anticipated since the electrical effect would be little modified by other terrestrial influences.

Specific Influence of Sunspots.—Since there is a relation between tornadoes and sunspots the question arises: Is this a general influence, or is there a specific effect of each spot as it appears by rotation? The latter view is held very tenaciously by some who claim that the first appearance of a spot is followed by an increase of storm influences on the earth, and that predictions of storms may be made from this appearance. This seems an important question. We notice, first: No attempt is made to explain what becomes of the spot influence after it passes the edge of the sun and moves toward the center; sec-

ond: As in the case of the planetists, earthquakes, storms, high winds, etc., all verify the spot appearance; third: Storms occurring anywhere on the face of the earth are also considered as a verification.

It would seem as though the only possible way in which this question can be properly discussed is to first take out the relative tornado intensity for each day, and then the relative spot intensity for the same days, considering in the latter case only the first appearance by rotation. All attempts at getting a statement of a scale of spot intensity, from day to day, from those who favor this hypothesis, have signally failed. We have, however, a most excellent measurement of sunspots on photographs at Greenwich, in India, and in Mauritius, day by day. These give the number and total area of each spot photographed from 1874 to 1886, and also its distance from the sun's center each day. I took the tornado months, March to September, and omitted the years with few spots—'77, '78 and '79. On comparing the appearance (when it was well on) of a spot with the tornado table I find that, first: Forty-six spots were coincident with tornadoes; second: 156 spots had no tornadoes, and third: 393 tornadoes had no spots. 46 : 595, this makes the percentage of coincidence eight, which is insignificant. I then considered three consecutive days of spots, that is, the date when it was well on and the two days succeeding and compared with the tornado table, in every case uniting three consecutive tornado days as one and also allowing a single tornado on any one of the three days to count for all three spot days. It will be seen that in this everything was favorable to the spot hypothesis. The years 1882, '83, '84 and '85 were taken, and the months April, May, June, July and August. There were 43 coincidences, 30 spot groups without tornadoes, and 79 tornado groups without spots: 43 : 109, this gives 28 per cent. in favor of the hypothesis: that is, if we take three consecutive days, after the spot is well on the sun's edge by rotation, we shall expect to find in a little more than half the cases at least one tornado of scale one somewhere in this country from about the 100th meridian to the Atlantic, but only 28 per cent. of coincidences in favor of the hypothesis. It is very plain that this would be of no use whatever to the forecaster.

General Influence of Spots.—It will be found that there are marked periods of solar activity and that after a spot has appeared it will increase in size at times, while at others its size

will diminish. In order to connect tornadoes with this phase of spot activity, curves were drawn showing the fluctuation of spots and of tornadoes.

It appears from these that with a few exceptions a rise in the tornado curve occurs when there are abundant spots, or just a little preceding a multiplication of spots. On the other hand a marked rise in, and continuation of intensity of the spot curve occurs very frequently without a response from the tornado curves. We may conclude on the whole that there is an increase in tornado and thunder-storm action during a maximum of sunspots, and while this does not bear a definite relation to the time of appearance of the spot by rotation, yet a marked increase in tornado action generally occurs during an increase in spot activity. The counterpart of this proposition, however, does not hold, and there may be an increase in spot activity without an increase in tornado frequency.

Cause of a Tornado.—A great deal has been written in this paper about tornadoes and an attempt has been made to array most of the facts known about them, but after all the most important point has been but barely alluded to. What is the cause of a tornado? We are in danger of setting out upon a boundless and unknown sea of speculation and theory, the moment we leave the solid ground work of fact. It would seem much easier to determine what a tornado is *not* than what it *is*. Most of the generally accepted theories certainly seem to be controverted by well known facts and also seem entirely inadequate to account for the phenomena observed. We have but begun to learn the great possibilities in electric actions, and this would seem the most promising field of study. It is conceded on all hands that we cannot account for a tithe of the atmospheric electricity observed, by considering it as the effect of growth in plants, evaporation from the sea, friction of winds upon the earth, etc. Why may not this atmospheric electricity be a product of the sun transmitted possibly through the agency of heat? It has been repeatedly observed through kite experiments that the electric potential is enormously increased at not more than 500 or 600 feet elevation. It is quite well known that thunder-storms pursue the same course year after year, and somewhat the same thing is known of tornadoes; for example, there are at least three strips in Illinois running from SW to NE where tornadoes seem more prevalent than elsewhere in the state. This may be due to certain portions of the earth's sur-

face being better conductors of electricity. It is known that the electricity of the atmosphere frequently differs in kind and intensity from that of the earth. Why may not the tendency toward an equilibrium bring about all the manifestations of power that are so terrible in the tornado? The great desideratum now is a positive knowledge of the change going on in our upper atmosphere and bringing about our storms and winds. Without this knowledge we are groping in almost profound darkness.

CONCLUSIONS.

1. A tornado is a sudden interjection of an outburst of nature's forces in an otherwise quiet region.
2. Electricity is a constant accompaniment, and is probably the most important force engaged in the action.
3. The velocity is about double that of the attendant storm, and hence the tornado is largely independent of that.
4. It almost invariably occurs in the SE quadrant of a general storm where there are no uprushing currents, no contrasts of temperature, no northerly winds meeting southerly, etc.
5. Tornadoes are propagated along parallel lines from SW to NE, frequently for a hundred or more miles, present every appearance of having their own source of energy, and are not maintained by a convenient upsetting of the equilibrium of the atmosphere directly in front and nowhere else.
6. The pressure of the air rises at the tornado center.
7. The distribution of debris shows a tendency to a downward and outward action rather than an inward and upward.
8. The destruction of strong structures and lack of injury to frail ones shows some force other than that of a high wind blowing into a partial vacuum.
9. The stripping of feathers from fowls shows the same.
10. All the phenomena that have ever been noted are easily explained on the supposition of electrical action and hardly any of them can be explained satisfactorily by the ordinary theories in vogue.

TORNADO DESTRUCTION.

It is much to be regretted that the description of tornadoes has become at the present time exceedingly vague and indefinite, and if not checked bids fair to become worse and to give an exceedingly erroneous idea of these storms. We are told, "If we care for the name tornado to define a distinct class of local storms, then the funnel-shaped cloud, as shown by a distinct

rotary movement of the wind, or (at night) by peculiar destruction of property (distribution of debris), should be made the consideration of classification. Both for the purpose of study and practical results this manner of distinguishing the tornado is desirable. It leaves no doubt as to where the line should be drawn and recognizes an important and peculiar class of meteorological phenomena, *independent of their effect upon life and property, which it is quite well known that they can destroy if given an opportunity.*" The italics are added. It is only necessary to add that this reasoning has permitted the promulgation of the statement that this country has lost over \$941,000,000 in tornadoes, a sum which is undoubtedly more than twenty times too great. It is manifestly only by the effects of these storms at the earth that we can classify or study them. The most violent commotions, the most surprising shapes and appearances of clouds, might have a passing interest, but surely they would be practically of no account if they did not reach the earth and there affect life and property.

The question of a proper classification of tornadoes seems of the highest importance. I am well aware of the extreme difficulty of estimating destruction in many cases, but we are not helped at all by giving the name of a county or counties through which a tornado has passed. I will give a single illustration. On September 9, 1884, a tornado caused destruction in portions of Minnesota and Wisconsin which has the reputation of being the most destructive tornado ever known, (\$4,000,000), and is designated as the Rock, Hennepin, Ramsey, and Washington counties, Minn., and the St. Croix, Polk, Barron, Chippewa, and Price counties, Wis., tornado. A most careful study of this tornado has been made with the following astounding result. The principal loss was at Clear Lake, Wis., (\$130,100), and the only other town seriously damaged was Marine, Minn., with a loss there and near by of about \$65,000. The total direct loss by this tornado was certainly under \$250,000, or one-sixteenth the loss usually ascribed to it. This is a single sample of illustrations that might be given by the score. While the total loss by tornadoes of class (3) is to be given yet it is not so easy to estimate the average loss by classes (2) and (1). A careful study of the question has shown that class (2) cannot have a loss of over \$25,000 each and class (1) about \$4,000 each.

In making up the list of 2,221 tornadoes it was often found entirely impossible to get the names of every town visited, and

in such case it was necessary to give the name of a county for the place of action. Care was always taken to make the number of tornadoes cover the entire loss. In many instances a very close estimate of the loss can be found. For example, on April 18, 1880, Marshfield, Mo., was devastated by a tornado. A careful statement giving the losses, in sums ranging from $8,000 to $50, shows the total loss to be $109,850. It might be thought that even this sum was too large, because each man would be inclined to place his loss a little greater than it actually was.

Loss by Hail, Rain, Floods, etc.—A frequent cause of overestimation of loss is due to the reckoning in of damage to wheat, orchards, etc., due to the violent hail, rain or floods which accompany the tornado. The only loss by a tornado is very distinct; it is in a very narrow path and not over several square miles of section. Certainly, in tornado insurance, the immediate and palpable destruction by the tornado is the only one that can be considered.

Comparison of Losses by Tornadoes and Fires.—Quite an interesting and possibly valuable comparison may be made between the losses by tornadoes and fires in this country in the seventeen tornado states. The following table explains itself:

Comparison of Losses by Tornadoes and by Fires in the United States from 1876 to 1884.

State.	NUMBER OF TORNADOES.			Total Loss.	Fire Loss.
	Class (3)	Class (2)	Class (1)		
Alabama......	3	30	8	$ 1,162,000	$ 6,169,000
Arkansas	3	21	18	877,000	6,419,000
Georgia	—	54	32	1,478,000	14,083,000
Illinois........	4	77	87	3,073,000	38,060,000
Indiana.......	1	42	30	1,245,000	22,981,000
Iowa..........	3	42	50	1,990,000	14,821,000
Kansas........	2	77	68	2,397,000	6,108,000
Michigan	—	24	18	672,000	30,583,000
Minnesota	2	20	23	1,192,000	18,752,000
Mississippi....	4	21	15	1,205,000	5,479,000
Missouri	7	61	45	2,600,000	27,129,000
New York.....	1	34	33	1,062,000	124,767,000
N. Carolina ...	—	18	11	494,000	6,486,000
Ohio	2	42	35	1,470,000	41,496,000
Pennsylvania..	—	22	22	638,000	69,869,000
So. Carolina...	1	24	12	848,000	7,747,000
Wisconsin.....	3	39	33	1,757,000	21,375,000
Total.......	36	648	540	$ 24,160,000	$462,324,000

In this table the total is made up from the estimated loss by class (3) while class (2) has been taken at $25,000 each and

class (1) at $4,000 each. Omitting New York and Pennsylvania the tornado loss is about one-tenth the fire loss. The Tornado Insurance companies are charging about the *same* for these two classes of risks.

Width of Path.--A great deal of uncertainty has arisen from the width of path given. For example, in the above tornado of September 9, 1884, which is given as passing through four counties in Minnesota, and five counties in Wisconsin, the width of path is 2,640 feet. Of course it is not intended to convey the idea that each of these nine counties was devastated throughout its length in such a path as this, but only at a single point or two was this width met with. However, the impression will be gained that the width of the path is an important element, which undoubtedly is a fact, but the width given must be very often not that of the tornado but of the high winds accompanying. If the width is given at all it should be that of the tornado track proper, which is seldom more than two hundred or three hundred feet, and not of the indrafts often extending to half a mile outside.

Evolution of a Tornado.—It would seem as though greater care should be exercised in recording and tabulating tornadoes. In one list, I have found, a tornado is set down as occurring at Jamestown, Dakota. On investigation it was found that no one had been within about fifteen miles of the alleged tornado in fact the only way even its approximate position could be ascertained was by prolonging the line of sight of two persons who saw it from two different points in different directions. The interest attaching to this alleged tornado is increased by the fact that there was a photograph taken of it. The photograph certainly does not look as if it were of a tornado. The dimensions of the camera used (which was eighteen miles from the spot) made the top of the tornado cloud three miles above the earth. As no tornado cloud was probably ever above 2,000 or at the most, 3,000 feet high, the existence of this tornado is exceedingly doubtful. It is probable that a cloud-burst was photographed and the camera could hardly have been more than two and a half or three miles from the cloud-burst. Now comes the sequel to this rather interesting episode. It seems that some one, desiring to make a wood cut of a tornado for a newspaper article, has chosen this very illustration, but the engraver, wishing to produce a more striking effect, has left off a good deal of the original illustration and has developed rather a striking picture.

In this wood cut, the tornado is placed at twenty miles and its height is increased nearly one-fifth. Taking the dimensions of the camera the final evolved tornado is more than three miles in height, about one-half mile in diameter at the top and one-fourth mile at the bottom. It is very fortunate that such evolutions are not often attempted.

LIST OF THE MOST VIOLENT TORNADOES IN THE UNITED STATES IN THE PERIOD 1873 TO 1888.

Every effort has been put forth to make this list complete. Several appeals for lists, where it was thought something might be had, have entirely failed. It has been found necessary to rely often on rather imperfect data. It does not seem possible however, that any noteworthy tornado can have been omitted.

In the reported destruction at Prescott, Kansas, of $1,000,000 April 21, 1887, no corroboration has been found, and I have recorded it as found in the *Weather Review,* though the amount seems excessive.*

There have been several serious tornadoes in Texas but that state did not come into these studies.

1. November 22, 1874. Montevallo, Shelby Co., Ala. (3). Town nearly half destroyed; loss $100,000, estimated.

2. November 22, 1874. Tuscumbia, Colbert Co., Ala. (3). Nearly half the town was destroyed; 12 killed, 30 wounded; 100 buildings destroyed and disaster to many other structures; loss $200,000, estimated.

3. May 6, 1876. Chicago, Cook Co., Ills. (3). Accompanied by rain, thunder and lightning from SW to NE, bounding like a ball, apparently reached the ground but two or three times; about $250,000 damage.

4. June 4, 1877. Mt. Carmel, Wabash Co., Ill. (3). Struck 4:30 P. M.; width 200 to 400 feet, length seven miles, velocity about 38 miles per hour; great destruction of property; 16 killed, 100 injured; loss $400,000.

5. July 7, 1877. Pensaukee, Oconto Co., Wis. (3). Moved from NW to SE; 1,000 feet wide, three miles long; lasting about two minutes; eight killed, many wounded; damage $300,000.

6. June 1, 1878. Richmond, Ray Co., Mo. (3). A dense,

*Since completing the above I have obtained a reliable statement of the total loss in the Prescott, Kansas, tornado. Prescott itself was a town of about 300 people and the loss aggregated $46,000. In the county the loss was $89,900. The total loss by a large estimate was less than $150,000.

muddy-looking funnel-shaped cloud united with another to the north; day intensely sultry; objects were drawn upward and then scattered broadcast; it moved slowly; it entered the city at 4:05 P. M. from the south, sweeping everything clean; heavy sills, 18 inches square and 16 feet long were swept away; trees were twisted contra-clock wise; path through city was 750 feet (three squares) wide and one mile long, in which space not a single house was left standing; loss $100,000, estimated.

7. August 9, 1878. Wallingford, New Haven Co., Conn. (3+). At 5:45 P. M. a dark cloud approached the village from west; "Electricity of the most terrific kind filled the air"; "Straight rods of fire came down from the sides of the cloud to the earth"; at 6 P. M. over a pond just west of village a cloud from SW united with this; the funnel-shaped cloud passed almost due east; its path was marked by the debris of houses, all the timbers and boards lying parallel to each other as though a mighty river had passed; 55 houses were destroyed besides other damage; 30 killed, 70 wounded; loss $250,000.

8. October 8, 1878. Monticello, Jones Co., Io. (3−). 5:30 P. M. tornado passed over southwestern part of the city; 21 buildings totally destroyed, and 42 others damaged; width of path 1,300 feet, length about 10 miles, its velocity 40 miles per hour; loss $100,000, estimated.

9. April 14, 1879. Collinsville, Madison Co., Ill. (3). Struck at 2:45 P. M., moving zigzag from WNW to ESE; width of path 1,200 feet, and length about three-fourths of a mile; lasted two or three minutes; destroyed about 60 buildings and injured several persons; in the cemetery nearly every stone was leveled; loss about $50,000.

10. April 16, 1879. Walterboro, Colleton Co., S. C. (3). Struck at 3:45 P. M.; path of destruction varied in width 600 to 2,700 feet; direction NE; rainfall following unprecedented; wind on north side had a downward crushing tendency, on south side an upward lifting motion; velocity of tornado 33 miles per hour; four people saw balls of lightning running along the ground, while others saw balls of fire in their houses during tornado; 11 killed; seven churches and 60 houses demolished; loss $200,000.

11. June 10, 1879. Delphos, Ottawa Co., Kas. (3−). Hail stones weighing 12 to 14 ounces; 32 buildings destroyed; two people fatally hurt and 14 injured; loss $100,000, estimated.

12. April 18, 1880. Fayetteville, Washington Co., Ark. (3+).

Track 300 feet wide, and not a single building in its course escaped; over 100 buildings destroyed; two killed, 20 to 30 injured; loss $100,000.

13. April 18, 1880. Marshfield, Webster Co., Mo. (3+). Near town, trees three feet in diameter, for a space of several hundred yards wide, were lifted entirely out of the ground; every house excepting six in this town of 2,000 people was destroyed; 65 killed and 200 wounded; loss $110,000.

14. April 18, 1880. Licking, Texas Co., Mo. (3−). Entire town destroyed except three houses; 300 persons left homeless; one killed, 17 wounded; loss $50,000.

15. April 25, 1880. Macon, Noxubee Co., Miss. (3−). Demolished 22 houses and other buildings; 22 killed and 72 injured; loss $100,000.

16. June 14, 1880. Glendale, Hamilton Co., O. (3−). Scarcely a house uninjured; scores of largest trees either uprooted or twisted off near the ground; loss $80,000.

17. April 12, 1881. Hernando, De Soto Co., Miss. (3−). Twenty-five buildings totally demolished; 10 persons killed; in some cases hail-stones size of hen's eggs; it is of importance that electricity or thunder were not reported; loss $50,000, estimated.

18. July 15, 1881. New Ulm, Brown Co., Minn. (3). Forty-seven buildings blown to atoms, 200 unroofed or destroyed; six killed, 53 wounded; 102 families homeless; loss in town $400,000.

19. September 24, 1881. Quincy, Adams Co., Ills. (3−). Twenty-one houses destroyed and 50 unroofed; trees uprooted; storm accompanied by terrific thunder and lightning; loss $100,000.

20. April 5, 1882. Stafford, Stafford Co., Kas. (3−). Seventy-eight houses blown down; one killed, several injured; loss $100,000, estimated.

21. April 18, 1882. Brownsville, Saline Co., Mo. (3). Fifty houses destroyed; large trees uprooted; 11 killed and 150 injured; $180,000 estimated loss.

22. May 8, 1882. Mt. Ida, Montgomery Co., Ark. (3). More than 100 buildings demolished; two persons killed, several injured; horses, etc., killed; $150,000, estimated.

23. May 8, 1882. McKinney, Cleveland Co., Ark. (3−). Fifty buildings destroyed; loss $30,000.

24. June 17, 1882. Grinnell, Poweshiesk Co., Io. (3+).

One hundred and forty houses reduced to ruins in five minutes; 60 killed and 150 injured; loss $600,000.

25. April 22, 1883. Beauregard, Copiah Co., Miss. (3—). Town of 600 people every house and store destroyed; 29 killed, 40 wounded; solid iron screw of cotton-press, weight 675 lbs., carried 900 feet; loss $450,000.

26. April 22, 1883. Wesson, Copiah Co., Miss. (3—). Twenty-seven houses destroyed; 13 killed, 60 injured; loss $20,000.

27. May 13, 1883. Kansas City, Jackson Co., Mo. (3—). Two hundred houses destroyed; loss in town $300,000.

28. May 18, 1883. Oronogo, Jasper Co., Mo. (3—). Nearly all houses destroyed; six killed, 33 wounded; loss $75,000.

29. May 18, 1883. Racine, Racine Co., Wis. (3+). One hundred and fifty houses destroyed; 25 killed and 100 injured; loss $200,000, estimated.

30. June 11, 1883. Brush Creek, Fayette Co., Ia. (3). Town one-third destroyed; loss $40,000.

31. August 21, 1883. Rochester, Olmstead Co., Minn. (3). Large part of town destroyed; 135 houses destroyed; 31 persons killed; length of path 18 miles; loss in county $200,000.

32. February 19, 1884. Leeds, Jefferson Co., Ala. (3—). Houses blown away; 11 killed, 31 wounded; 27 houses entirely destroyed and many barns; hail of unusual size; loss $80,000, estimated.

33. February 19, 1884. Bird's Point, Mississippi Co., Mo. (3—). Forty houses badly damaged; very large hail; loss $80,000, estimated.

34. April 1, 1884. Oakville, Delaware Co., Ind. (3—). Town almost entirely destroyed; 27 houses wrecked; 50 persons injured and four killed; loss $75,000, estimated.

35. April 27, 1884. Jamestown, Greene County, O. (3). Two-thirds of buildings ruined; six persons killed; loss $200,000.

36. July 21, 1884. Dell Rapids, Minnehaha Co., Dak. (3—). Loss $100,000.

37. September 9, 1884. Clear Lake, Polk Co., Wis. (3). Greater part of town in ruins; 40 buildings destroyed; three persons killed; loss $150,000.

38. September 28, 1884. Shongo, Alleghany Co., N. Y. (3). Twenty-six buildings some of which were the most substantial

of the place destroyed; two persons killed and 20 injured; 40 to 50 rods wide; loss $80,000, estimated.

39. August 3, 1885. Camden, Camden Co., N. J. (3+). Five hundred houses unroofed or blown down; six persons killed; 100 injured; path from one to two squares wide; loss $500,000.

40. September 8, 1885. Washington C. H., Fayette Co., O. (3+). Town almost destroyed; 40 business establishments and 200 residences destroyed; six persons killed, 100 injured; loss $500,000.

41. April 14, 1886. Saint Cloud and Sauk Rapids, Minn. (3−). Seventy-four killed, 136 wounded; 138 buildings destroyed; loss $400,000.

42. May 12, 1886. Attica, Fountain Co., Ind. (3). Two hundred houses destroyed; 12 persons injured, 100 to 200 yards wide; loss $200,000.

43. April 15, 1887. St. Clairsville and Martin's Ferry, Belmont Co., O. (3). About 200 buildings of all kinds destroyed; loss $250,000.

44. April 21, 1887. Prescott, Linn Co., Kans. (3+). Three hundred and thirty (?) buildings destroyed; 20 (?) killed, 237 (?) wounded in county (?); loss $150,000.

45. April 22, 1887. Near Mt. Carmel, Wabash Co., Ills. (3−). Everything in path destroyed; two killed, several wounded; loss $50,000.

46. April 22, 1887. Near Clarksville, Johnson Co., Ark. (3). Destroyed everything in path; 20 killed, 75 to 100 injured; loss $150,000.

47. June 16, 1887. Grand Forks, Grand Forks Co., Dak. (3). Fifty or more houses, besides hundreds of barns, etc., destroyed; four killed; loss $150,000.

48. February 19, 1888. Mt. Vernon, Jefferson Co., Ill. (3+). Large part of town (8000 inhabitants) destroyed; 18 killed, 54 wounded; 100 buildings destroyed; loss $400,000.

LIST OF FORTY-EIGHT TORNADOES AND LOSS OF PROPERTY IN THEM.

	Date.	Town.	Loss.
1	November 22, 1874.	Montevallo, Ala.	$ 100,000
2	November 22, 1874.	Tuscumbia, Ala.	200,000
3	May 6, 1876.	Chicago, Ill.	250,000
4	June 4, 1877.	Mt. Carmel, Ill.	400,000
5	July 7, 1877.	Pensaukee, Wis.	300,000

	Date.	Town.	Loss.
6	June 1, 1878.	Richmond, Mo.	$ 100,000
7	August 9, 1878.	Wallingford, Conn.	250,000
8	October 8, 1878.	Monticello, Io.	100,000
9	April 14, 1879.	Collinsville, Ill.	50,000
10	April 16, 1879.	Walterboro, S. C.	200,000
11	June 10, 1879.	Delphos, Kan.	100,000
12	April 18, 1880.	Fayetteville, Ark.	100,000
13	April 18, 1880.	Marshfield, Mo.	110,000
14	April 18, 1880.	Licking, Mo.	50,000
15	April 25, 1880.	Macon, Miss.	100,000
16	June 14, 1880.	Glendale, O.	80,000
17	April 12, 1881.	Hernando, Miss.	50,000
18	July 15, 1881.	New Ulm, Minn.	400,000
19	September 24, 1881.	Quincy, Ill.	100,000
20	April 5, 1882.	Stafford, Kan.	100,000
21	April 18, 1882.	Brownsville, Mo.	180,000
22	May 8, 1882.	Mt. Ida, Ark.	150,000
23	May 8, 1882.	McKinney, Ark.	30,000
24	June 17, 1882.	Grinnell, Io.	600,000
25	April 22, 1883.	Beauregard, Miss.	450,000
26	April 22, 1883.	Wesson, Miss.	20,000
27	May 13, 1883.	Kansas City, Mo.	300,000
28	May 18, 1883.	Oronogo, Mo.	75,000
29	May 18, 1883.	Racine, Wis.	200,000
30	June 11, 1883.	Brush Creek, Io.	40,000
31	August 21, 1883.	Rochester, Minn.	200,000
32	February 19, 1884.	Leeds, Ala.	80,000
33	February 19, 1884.	Bird's Point, Mo.	80,000
34	April 1, 1884.	Oakville, Ind.	75,000
35	April 27, 1884.	Jamestown, O.	200,000
36	July 21, 1884.	Dell Rapids, Dak.	100,000
37	September 9, 1884.	Clear Lake, Wis.	150,000
38	September 28, 1884.	Shongo, N. Y.	80,000
39	August 3, 1885.	Camden, N. J.	500,000
40	September 8, 1885.	Washington C. H., O.	500,000
41	April 14, 1886.	St. Cloud and Sauk Rapids, Minn.	400,000
42	May 12, 1886.	Attica, Ind.	200,000
43	April 15, 1887.	St. Clairsville, O.	250,000
44	April 21, 1887.	Prescott, Kan.	150,000
45	April 22, 1887.	Mt. Carmel, Ill.	50,000
46	April 22, 1887.	Clarksville, Ark.	150,000
47	June 16, 1887.	Grand Forks, Dak.	150,000
48	February 19, 1888.	Mt. Vernon, Ill.	400,000
	Total loss, ...		$8,900,000

NOTES ON OTHER THEORIES.

(*General.*) *Limited Heating of the Earth.*—It is taught that the sun heats up a limited portion of the earth and this begins

the uprush. Since the maximum temperature of the day continues about an hour, we see that a region at least 1000 miles in diameter must be uniformly heated. Moreover, experiments have shown that the heat of the earth's surface extends only a few feet upward, so that this effect would be inconsiderable.

Occurrence in SE Quadrant of Low.—All theories were based originally on the idea of the formation of the tornado at the center of an extended storm region. Here all the winds appeared to radiate and this necessitated an uprush, or the bendings of the isobars would be very rapidly obliterated. We now know that the seat of tornado action is about 400 miles to the SE of the general storm center. In this region the winds and currents are gentle and from the south, even up to the clouds. There are no cool north winds meeting warm ones from the south. Nor does it help matters to carry the north winds into the upper current, for it is supposed by some that the tornado is carried in this current, and as its motion is toward the northeast the upper current must be from the southwest and not from the north.

Temperature.—In this region the temperature is uniformly high, but there are no contrasts of temperature at all till we reach the general storm center 400 miles away.

Cool North Winds Over-running Warm South Ones.—We are taught that an unstable equilibrium is produced by a warmer stratum trying to push its way through the cool stratum above it, but it would seem as though in a frictionless medium no such effect would ever take place. The denser would invariably under-run the lighter, and, in fact, this is the theory held by some, namely, that an unstable equilibrium is produced when the lower air is forced upward by cooler air under-running it.

(*Specific*). *Contrasts of Temperature.*—Few theories of tornado action have been so universally held and so often repeated as this, namely, that currents of different temperature meet and in the warring of the elements the tornado is evolved. This theory was originally based upon the supposed fact that a cold cloud, near the earth, from the northwest, met another warm one from the southwest. As we have just seen, this is not the fact, that this meeting is an optical illusion. It is a singular fact worthy of mention, that this theory is losing ground, and its advocates are now considering that the cold wind is an upper current from the north and that this overflows the warm south

wind. This virtually abandons the old idea of the NW and SW clouds meeting for the affray.

Columns of Air of Different Density.—It is held by some that columns of air of different density exist and that in those of less density there is an uprush. It would seem probable that in a frictionless medium such columns would be highly hypothetical. Even if such a condition were begun the denser air would immediately flow in and destroy it.

Upper Part of the Tornado Reforming Itself in Front.—Since the friction at the earth's surface would retard the lower part of the tornado more than the upper, the two parts would quickly be separated. We are taught that the upper part reforms itself in front and then communicates its gyrations through the air to the earth. It does not seem possible, however, that such reformation could communicate its energy rapidly enough through a frictionless medium.

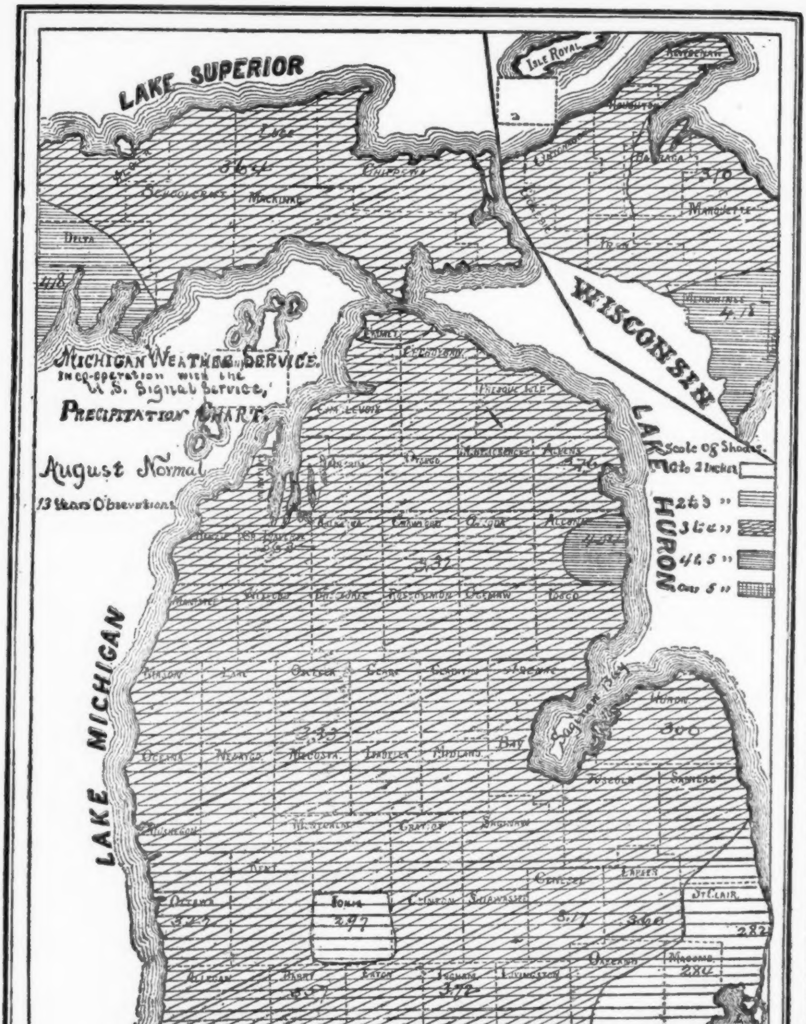
Motion of a Tornado.—The most extraordinary demand on our credulity made by the ordinary theories is that the tornado is produced by an unstable equilibrium and that its energy can only be kept up by this, and hence this unstable equilibrium must take place in the air just in front of the tornado and nowhere else in all this region of warring winds, enormous contrasts of temperature, etc. This most assuredly cannot be the case. Even if an unstable equilibrium were begun, it would have no power of maintaining itself. The moment the tornado began to move, its axis would be inclined to the vertical, and the conditions needed to sustain the instability would be almost immediately overthrown. The uprushing current in the centre demands that the axis be vertical.

It certainly seems as if the ordinarily accepted theories are entirely insufficient to explain the phenomena noted, and moreover in many cases they do violence to well ascertained facts.

RAINFALL IN MICHIGAN—AUGUST.

By N. B. Conger,
Director State Weather Service.

The average rainfall for the month of August is 3.20 inches, the average being computed from fifteen years' observations, and ranges from 2.72 inches in the southern section to 3.64 inches in the upper peninsula.


LAKE SUPERIOR
ISLE ROYAL
WISCONSIN
MICHIGAN WEATHER SERVICE.
In co-operation with the
U. S. Signal Service.
PRECIPITATION CHART.
August Normal
13 Years Observations
Scale of Shades.
LAKE HURON
LAKE MICHIGAN
Saginaw Bay
INDIANA
OHIO
LAKE ERIE

It will be noticed that the amount of rainfall has increased in a northeasterly direction. The heaviest is now in the upper peninsula; it slowly decreases towards the extreme southeast portion of the state, where the average amount is a trifle over 2.50 inches. It will be noticed on examination of the July chart that the shades are nearly reversed in the August chart, and the increase has progressed along the west shore of the state.

The extreme southeast portion of the state is the portion most liable to droughts during this month, and the rainfall in this section has ranged from 0.14 inch in 1889 to an average of six inches in 1882. There have been four seasons in the past fifteen years in which the average amount of rainfall here for the month was below one inch.

The prevailing winds during August are from the southwest, and the most rainfall would be expected on the west side of the state, or where both sides were affected by the moisture-ladened winds from the lakes, as will be noticed in the upper peniusula. As in July, thunder-storms prevail during this month, and large amounts of rain are deposited during these storms, and as, in this state, they travel generally from the southwest to the northeast, the line of heavy rainfall will be found to follow the same path. As has been before intimated in these papers, in the distribution of rainfall in the state, it is found that droughts do not prevail over the entire area of the state at the same time, but only in different sections. There is generally sufficient rainfall in the adjoining sections to materially aid the section that is suffering most severely, by moistening the air that passes over the dry section. The dry spell of 1889 was general over the entire south half of the state, but this is the only one on the records of the service, and during this same period the average rainfall at St. Ignace for August was 4.04 inches, bearing out the above statement.

A NEW RECORDING RAIN AND SNOW GAUGE.

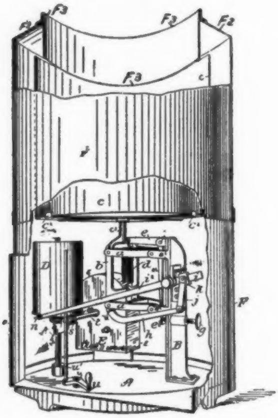
By S. P. Fergusson.

A brief description of this instrument appears in this Journal for November 1888. Since then improvements in its construction have been made, and it is thought that a more detailed description with illustration would be of interest.

In principle, the instrument is similar to the one designed by

Mr. Rotch and used at Blue Hill Observatory since March, 1886, which was probably the first to successfully record amounts of unmelted snow. The intention has been to devise an apparatus that would be less costly than others now in use without loss of efficiency; and experiments with a few instruments made during the past year show the new gauge to be very reliable and inexpensive, the cost being $50.

The levers *a*, *a*, *e*, spring *d* and upright frame *b* form a spring balance which supports, by arms c^2, c^2, the receiving vessel *c*. Into this receiver projects the cylindrical spout or funnel F^3, which is secured to the upper casing F^2. From the frame *b* of



the spring balance extends an arm *h* which is connected with the recording lever *i*, i^2. This lever carries a pen which touches the cylinder *D*, around which is secured a paper sheet for receiving the record. This cylinder is rotated once in twenty-four hours by a clock in the case *E*, with which it is connected by means of the shaft *t* and gearing *s*. The outside casing *F*, F^2, protects the working parts from injury. A door (not shown in cut) allows access to the apparatus near the bottom, and the upper casing F^2 is removable for purposes of emptying the receiver, etc. A "dash-pan" or damper prevents oscillations of the apparatus caused by wind. It consists of a plunger attached to a projecting arm of the spring balance and working in a vessel filled with oil, the resistance of which, to the plunger, checks sudden vibrations of the spring balance. The thumb-

screw g is for adjusting the pen to the zero of the chart when on the record cylinder; also the sliding block k may be moved in or out to correct the instrument when it records too large or too small an amount. The pen may be moved from contact with the surface of the cylinder D by means of the lever u, u^1.

The action of the apparatus is very simple. The weight of the precipitation falling through the spout F^3 into the receiver c depresses the spring balance, causing the recording lever i, i^2 to rise, the pen making an upward trace on the cylinder D, which is covered wtth a sheet of paper ruled horizontally to inches and tenths, and vertically to hours and convenient fractions, thus enabling the amount of rain or snow, etc., to be obtained for any hour of the day.

Two of these gauges, in use at Blue Hill Observatory during 1889, have given excellent records, also instruments recently installed at the Boston Water Works, and at Harvard College Observatory are working satisfactorily.

CORRESPONDENCE.

ASHEVILLE AS A RESORT FOR INVALIDS.

To the Editors: Edward Everett Hale gives one of his characteristically amusing chapters to describing the manner in which an English tourist visited nineteen of the United States in thirteen days, during which time he was enabled to form profound judgments upon the manners, customs and characters of the various inhabitants. Somewhat similar is the task which you set me when, in Nashville, you asked me to "write up Asheville." I staid in Asheville one whole delightful week. I arose before sunrise and climbed up the mountain, above the clouds, to see the sun rise. Tramped morning, noon and night, over the hills, through the woods—had a memorable horseback ride upon a big black horse and otherwise disported myself, but, like the monstrous shadow which affrights the traveller upon the Brocken, there arose before me forever the spectre that I must "write up Asheville." Your readers do not want an account of my celebrated horseback adventure, still less would they enjoy a series of statistics upon the altitude, the average or mean or extreme temperature or moisture, the number of hours of night or day, cloud and sunshine. They can get any

quantity of figures from other sources. Let me give them simply the thoughts of an every day doctor about Asheville and invalids. I think many doctors and most patients forget, or fail to realize, why they go to Asheville or any other climatic resort. The practical result is that a considerable number of patients go to Asheville who have no business to be there, who ought to be at home. The essential reason why we send our pulmonary or bronchial sufferers to Asheville is to put them in an atmosphere such that they can inhale it without irritating their already irritated lungs—that they can inhale it out of doors with considerable regularity, and by so doing enable the general nutrition of the body to improve with the subsequent improvement of the resistance of the body tissues to micro-organisms. Now the patient whose lungs are riddled with cavities, whose mesenteric glands are enlarged, who is overwhelmed with tubercles, may die comfortably in Asheville, but not as much so as he would at home. To the patient who has considerable good working lung tissue remaining I can say that Asheville affords the following advantage—a climate in winter, such that on almost every day he or she can get out of doors and remain out a pretty fair share of the day. But let the prospective patient know this; he will find poor sidewalks—very poor—so that he cannot walk far—red clay roads which, when wet, still further limit his morning rambles. He should realize that while Asheville is set with mountains all around about it, is quite a sizeable town, so that in general he or she will look across the street or out of his back window upon a foreground of other boarding houses or passing darkies.

The patient need not, in general, expect to find the glories of mountain scenery in the back yard of his boarding house. It should also be stated in justice to Asheville landlords and ladies that pretty much every decent edible substance, except peanuts and sweet potatoes, comes from the north—meats by express from Chicago, ice from Lake Superior, butter from Michigan. The traveler from the north ought to realize, as his express train flies by the freight train, that his prospective good dinner is following him along to Asheville and must be paid for. I incline to think that I ought hardly to mention "his good dinner,"—let us call it "his tolerable dinner," for even good Chicago tenderloins seem to suffer under the manipulations of a southern cook.

If now, your prospective patient has enough vigor of appetite to withstand the cook—enough lung tissue to supply his mus-

cles with oxygen sufficient to encounter the sidewalks, or ride or be driven (good horses can be procured, barring big black "John," and good vehicles), then indeed, the patient can find, within a short distance of his boarding house, a view of mountain scenery which is perpetually fine; he can find all the invigoration of mind and body which the air of the hills and forests can give.

But now I must apply the wet blanket again. Many a patient fails to consider, that as a patient, his reserve of bodily force is diminished. Here are the balmy breezes, the inviting mountain roads, the charm of new and beautiful scenery; he has come on purpose and at much expense to procure these things, and presently the patient who, at home, did not walk around the block, is found panting on some hillside—the patient whose longest drive at home was on a smooth road for half a mile, is jolting down some mountain road. It is very delightful, but the subsequent rise of temperature, the cough and the next day's prostration are discouraging. It takes just as much expenditure of bodily force to climb four hundred feet in Asheville as it does in Washtenaw county. I have spoken so far, as if the patient were some sufferer from trouble in his respiratory apparatus, because the majority of the patients who contemplate going to Asheville are such, and certainly the fact that pulmonary tuberculosis does not occur at all among the permanent residents of Asheville, is of itself good reason for this. Before leaving the matter of pulmonary patients I want to emphasize one thing. It certainly does not seem like good sense for a patient who has required the careful and regular supervision of his home physician to go to some boarding house in Asheville and suspend all intelligent medical supervision. I should strongly advise patients to put themselves under such guidance while in any health resort. At Asheville there are several excellent physicians, and for pulmonary cases, a sanitarium conducted by Dr. von Ruck. The Sanitarium has the, to many patients, very great advantage of the patient having immediate attendance in emergencies. The diet is good and (unlike the larger hotels) modified to suit the needs of the sick. The Sanitarium building stands at the extreme outskirts of the town up on the hillside and close to the favorite mountain drives.

Leaving now the special suggestions for pulmonary sufferers, I wish to bring out one thought which constantly occurred to me in Asheville. We send our pulmonary patients to these

resorts, study the peculiarities and advantages of them, but our nervous cases are apt to receive much less wise consideration. Personally, I believe that a sanitarium for nervous diseases in Asheville would accomplish much greater and more prompt benefit than one for lung affections. When, the other day, I saw a broken down millionaire whose life has been one "demnition grind," who knew as little how *to play* as he did how to copy Raphael, I thought that even his prosaic soul might be stirred by the surroundings of the mountains; he might look up from his cash book to the passing clouds, might stop looking at his unsatisfactory inner man to find an interest outside of himself. Sentiment, I hear you say? No sentiment about it! Fact! Our nervous patients need this very thing to withdraw them from themselves. The mountain air is just as good a sedative to brain cells as it is to the cells which line the bronchi. Improved metabolism is good for one as for the other. And the worn out man of the desk or pulpit or counter has the advantage over the lung man that he can climb and tramp to his heart's content. If all else fails, I am certain that a ride on big black "John" would arouse the worst melancholic you ever saw.

Yours truly,

DAVID INGLIS, M. D.

CURRENT NOTES.

THE TORNADO ESSAYS.—Our readers will notice that this issue of the JOURNAL is a double number, and includes the prize tornado essays. The essays are of great interest in that they give the present state of opinion and observation in America on these storms. We have decided to print a small number of extra copies of the essays, which will be bound together and sold for twenty-five cents per copy. They can be obtained of the publishers of the JOURNAL.

PROFESSOR FERREL'S PUBLICATIONS.—A list of them is given in *The Naturalist*, published at Kansas City, Kansas (not Missouri), in the number for December, 1889. It includes fifty-two titles, without the translations and republications which are quite numerous. They range in time from 1853, and in number of pages up to the 504 of the recent "Popular Treatise on Winds."

THE MEXICAN CENTRAL METEOROLOGICAL OBSERVATORY.—Professor Mariano Barcena, director of the observatory, has been elected governor of the State of Jalisco. During his absence at this post the personnel of the observatory has been reorganized. Don Miguel Peres is the director. The force includes a vice-director and four observers.

FOSSIL BLIZZARDS.—Geological indications of ancient climates are of great interest and their study presents a field which does not seem to have been yet sufficiently studied. One of the most recent and novel suggestions on this subject is that of Dr. Nehring, in the *Naturw. Wochenschrift*, that the curious abundance of relatively recent fossils of large animals, which occurs quite often in limited areas, may be due to deaths caused by blizzards. It has been customary to account for such collections as the work of floods or of beasts of prey. But blizzards are very destructive to the larger animals when on plains and unprotected, and animals perishing in this way are generally huddled together for mutual protection and warmth. Besides, on sandy plains or tundras subject to blizzards, the wind would soon cover up such animals with snow and sand, thus leaving them in the undisturbed positions taken when freezing. A characteristic of the remains of animals which met their death in this way would be the preservation of natural and unstrained positions among their bones, and this would not be the case where the collection was due to floods or to carnivorous beasts. It is exactly this feature of natural position which characterizes the fossils in some of the places rich in them.

SHALL WE FLY?—The problem of aerial navigation is receiving more attention than is generally suspected by the public. Several very competent men are privately at work on it in this country and a rational expectation may be fairly entertained that the problem is approaching a successful solution. As an indication of the change of view on this subject by conservative *savants*, we quote the remarks of M. Janssen, an eminent astronomer and a member of the French Institute. In an address to the aeronautic congress at Paris last summer, he said:

Aerostation appears to me to be at a remarkable, but critical, epoch of its development. Following the indescribable enthusiasm provoked by the memorable discovery of the Montgolfier brothers, there came

period of indifference, as it were of disillusion. It was thought at first that the discovery of the art of rising in the air solved the problem of conquering the atmosphere. It was not so. To-day the problem of support in the air by principles of hydrostatics is one of the easiest to solve, but quite otherwise is it with the problem of directing one's course, even to a slight degree, whether by a profound knowledge and skillful use of the atmospheric currents or by the employment of mechanical means for overcoming these currents. This is a matter of extreme difficulty and its difficulty is especially great for those who seek to solve the problem mechanically and demand, after the example of the bird, both support and progression from their apparatus. . . .

In spite of the difficulty of the problem, I do not expect that man will take as much time to conquer the air as he took to conquer the sea. . . . I have a profound conviction,—and believe that in speaking thus I neither give reins to my imagination, nor permit myself to be led astray by my desire to please you; no, it is from a mind habituated to only consider the positive and certain elements of questions, and to admit only vigorous consequences; it is, in a word, the man of science who speaks now:—I do not hesitate to predict that the twentieth century, which is now close upon us, of which we can now salute the aurora, will see realized the great applications of aerial navigation. The atmosphere will then be furrowed by apparatuses which will definitely take possession of it, whether for its daily and systematic study, or to establish communications and relations between nations, making continents, seas and oceans a mere by-play. And two centuries or less will suffice for this prodigious result! There are those among you who will live to see the sunrise of that great day!

Publications of the Observatory of Rio Janeiro.—The serial publications of the Observatory are three in number. The *Revista* is a monthly of sixteen large octavo pages. It contains official notices, accounts of meteorological or astronomical observations, and papers of a somewhat popular character on topics related to the two sciences to which the Observatory is devoted. This journal is now in its fifth year. The *Annuario* is a duodecimo (of 326 pages for 1890), made somewhat after the plan of the French *Annuaire du Bureau des longitudes.* It contains a calendar, ephemerides, other astronomical data, meteorological, hypsometrical, other physical, chemical, and money exchange tables. While resembling its now aged French predecessor, it shows abundant signs of independence. The meteorological data for Brazil are few, but that is because, until very recently, few observations had been made. We note a table of mean temperatures for twenty stations in Brazil, the period of observation being, however, generally very short. Among these is Rio Janeiro (23.4° C.) with a period of 36 years;

S. Bento das Lages (Bahia) fourteen years (24.9° C.); Porto do Rio Grande do Sul, nine years (18.8° C.); Joinville, eight years (20.6° C.); Recife, eight years (26.2° C.); Victoria in the province of Pernambuco, seven years (25.1° C.). The absolute maximum temperature at Rio has been 37.5° C. and the minimum 10.2° C., giving a range of 27.3°. This is in latitude 23° S and altitude 66m. At the Bahia station mentioned, in latitude 12° S, the absolute temperatures and range were 38.5°, 16.2°, 22.3°. The *Annuario* is now in its sixth year.

The third publication of the Observatory is the *Annales*, an occasional stately quarto. The fourth, and latest, volume is in two parts. The first part is devoted to astronomy, the second, dated 1889, and containing 406 pages, contains the meteorological observations for 1883 to 1885, at Rio, in detail. The observations are tri-hourly. The results for rainfall previously published require a correction which is introduced into this volume.

Royal Meteorological Society.—The usual monthly meeting of this Society was held on Wednesday evening, the 18th of June, at the Institution of Civil Engineers, 25 Great George Street, Westminster. Mr. Baldwin Latham, F. G. S., President, in the chair.

Mr. C. C. Farr, B. Sc., Mr. J. Hall, A. M. Inst. C. E., Mr. C. R. Revington and Dr. J. L. Whitehead, were elected Fellows of the Society.

The following papers were read:

1. "On the difference produced in the mean temperature derived from daily maximum and minimum readings, as depending on the time at which the thermometers are read," by Mr. W. Ellis, F. R. A. S. In the publications issued by the Greenwich Observatory authorities, the maximum and minimum temperatures are those referring to the civil day from midnight to midnight. At many stations the observers only read their instruments once a day, viz., at 9 A. M., when the reading of the maximum thermometer is entered to the preceding civil day, and the reading of the minimum thermometer to the same civil day. Such stations are called "Climatological Stations." The author has tabulated the Greenwich maximum and minimum temperatures according to both methods for the years 1886–89, and finds that the climatological maximum and minimum means are in excess of the civil day means.

2. "On the distribution of barometric pressure at the average

level of the hill stations in India, and its probable effect on the rainfall of the cold weather," by Mr. W. L. Dallas. The weather over India during January, 1890, was very dry and in marked contrast to that which prevailed during January, 1889. The distribution of barometric pressure was, however, much the same in both months. The author has investigated the records at the hill stations, and has prepared charts showing the distribution of barometric pressures from both high and low level stations. From the high level charts it appears that the mean barometric gradient in 1889 was rather more than twice that in 1890, and considering what is known of air movements, even at moderate elevations above the earth's surface, it may be assumed that these differences in pressure were accompanied with large differences of air motion; and if it is also assumed that the evaporation over the Southern Ocean is in all years fairly comparable in amount, the deficiency of rainfall over India in the winter of 1889–90 can be attributed to diminished lateral translation of vapor owing to sluggish movements in the upper atmosphere.

3. "On the relative prevalence of different winds at the Royal Observatory, Greenwich, 1841–1889," by Mr. W. Ellis, F. R. A. S. The author gives the following as the average number of days of prevalence of different winds for the 49 years, 1841–89, as derived from the records of the self-registering Osler anemometer:

N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
40	45	27	22	35	106	46	22	22

4. "On some recent variations of wind at Greenwich," by Mr. A. B. MacDowall.

5. "On the action of lightning during the thunder-storms of June 6th and 7th, 1889, at Cranleigh," by Capt. J. P. Maclear, R. N. The author examined a number of trees which had been struck by lightning during these thunder-storms, and found that those which were struck before the rain fell were shattered, while those which were struck after the rain commenced were simply scored, with the bark blown off. It seems that during rain every tree is conducting electricity, and a disruptive discharge takes place where the conductor becomes insufficient. This depends on the position of the cloud, the amount of foliage on the tree, its condition of moisture, and its connection with running water.

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